

LIBRARY OF CONGRESS.

Chap. _____

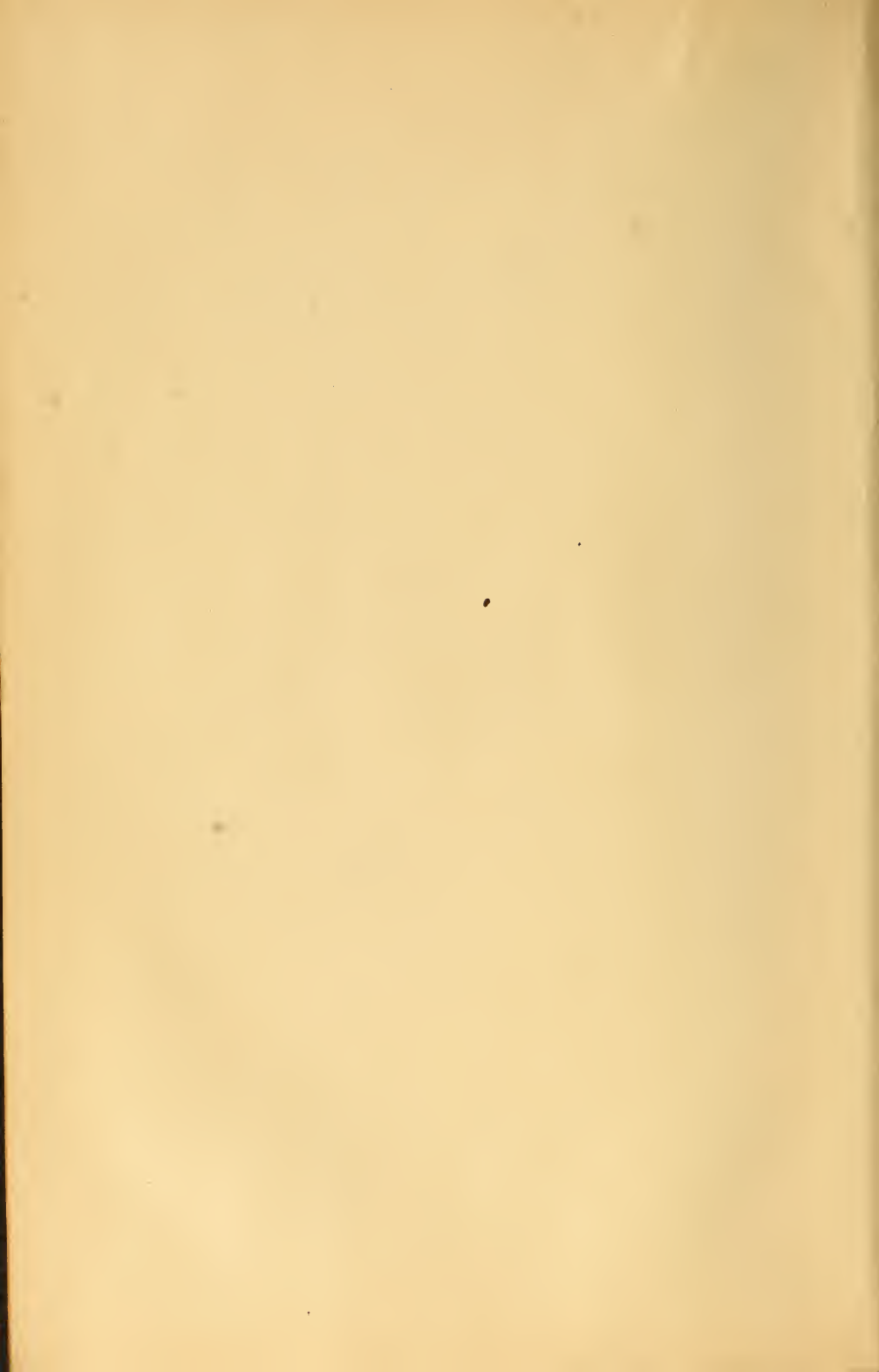
VM731

Shelf _____

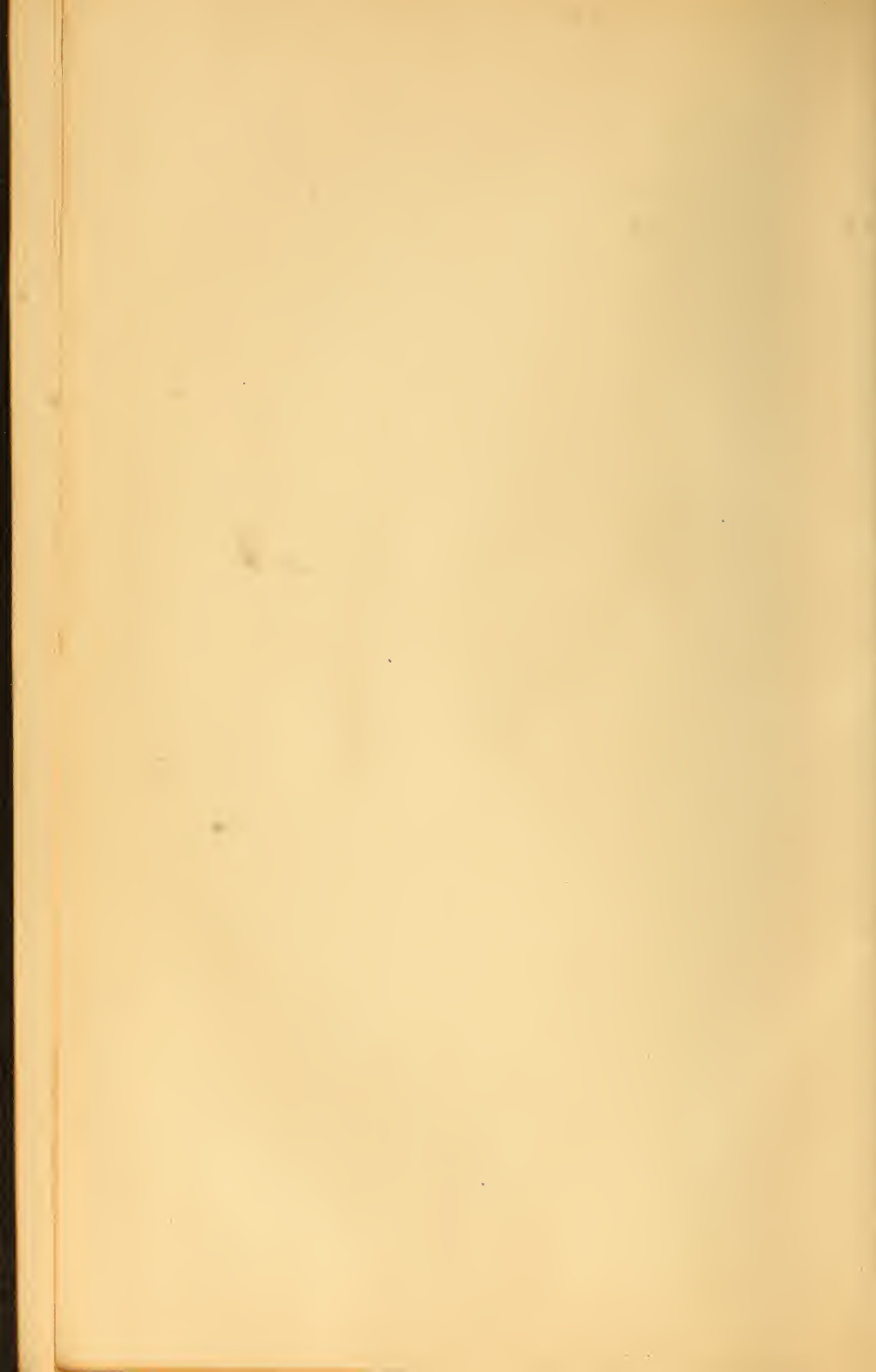
.L84

UNITED STATES OF AMERICA.

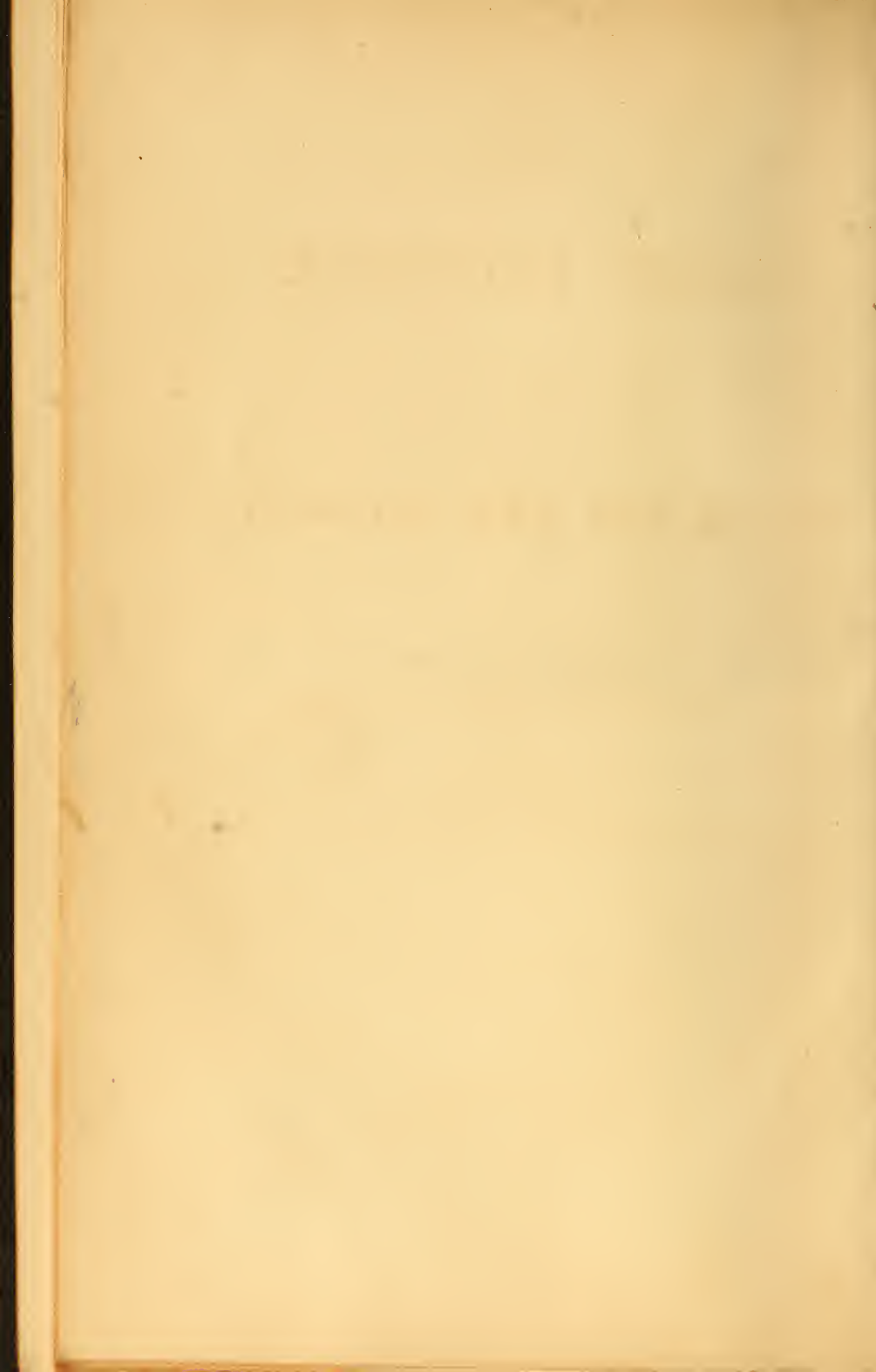








THE CADET ENGINEER.



4475

THE

CADET ENGINEER

OR

STEAM FOR THE STUDENT.

BY

JOHN H. LONG

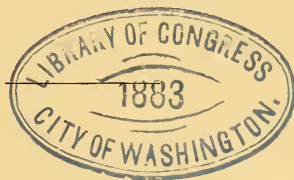
CHIEF ENGINEER UNITED STATES NAVY

15.75
✓ 9431

AND

R. H. BUEL

ASSISTANT ENGINEER UNITED STATES NAVY.



PHILADELPHIA:

J. B. LIPPINCOTT & CO.

1865.

Vol 931
1844

Entered, according to Act of Congress, in the year 1865, by
J. B. LIPPINCOTT & CO.,
in the Clerk's Office of the District Court of the United States for the Eastern
District of Pennsylvania.

663 of 1007
RESPECTFULLY INSCRIBED

TO THE

Young Engineers

OF THE

U. S. NAVAL AND MARINE SERVICE.



P R E F A C E .

IN this little work we have designedly avoided deep theoretical research, and have aimed rather to supply practical information.

Theoretical works can be obtained in profusion, but treatises on the practical part of engineering are more rare. It is to be hoped that the idea of introducing familiar topics, and things that (in common parlance) everybody knows, will meet with favor.

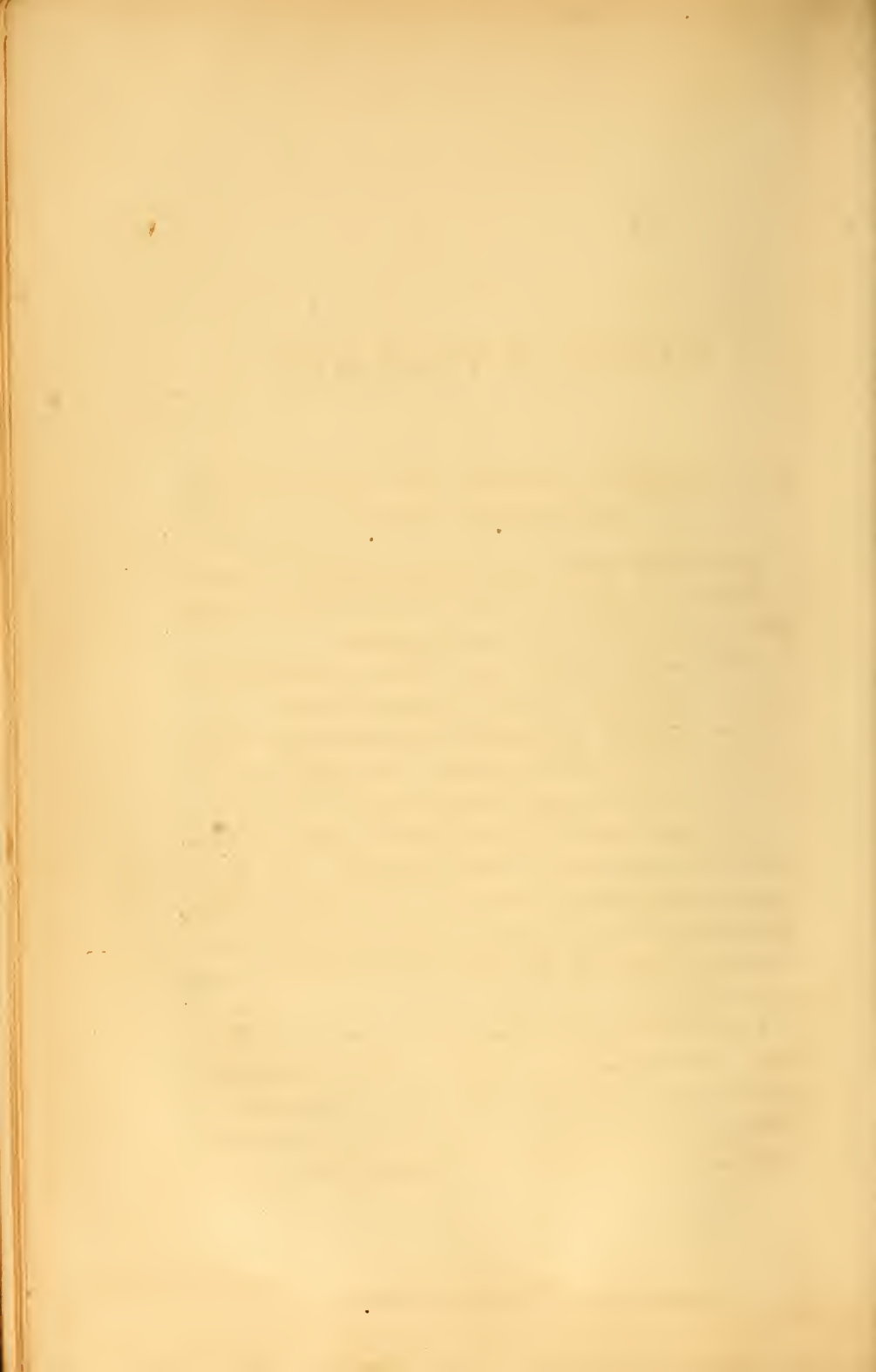
The practical man will here find his experience in print, and to seekers for information these notes may be of some service.

NORFOLK NAVY YARD, VIRGINIA,
MARCH, 1865.



TABLE OF CONTENTS.

ARTICLE	PAGE
PREFACE	vii
1. Description, advantages, and disadvantages of various kinds of Engines	11
2. Description, advantages, and disadvantages of various kinds of Boilers	14
3. Appendages to Engines and Boilers	17
4. The Paddle-Wheel	21
5. The Screw Propeller	37
6. Combustion of Coal	63
7. Erection of Engines	69
8. Steam	73
9. Expansion of Steam	75
10. Cut-Offs	88
11. The Indicator	95
12. The Slide Valve	108
13. Balanced Valves	117
14. Saturation of water in marine boilers, scale, and the means of preventing its formation	123
15. Condensers and Feed-water Heaters	132
16. Relations of power (or fuel) and speed in steam navigation	140
17. Management of Engines and Boilers at Sea	145
18. Overhauling the Engines and Boilers in port	161
INDEX	173



THE

CADET ENGINEER.

§ 1. *Description, advantages and disadvantages of various kinds of Engines.*

Engines are either single-acting, rotative, or rotary.

Rotative engines are classed as side-lever, beam, direct, back-acting, and geared engines.

Direct-acting engines are termed oscillating, inclined, horizontal, vertical, or trunk engines.

The principal advantage of the side-lever engine is, that it is equally balanced. Its disadvantages are, its excessive weight and the space it occupies.

The beam-engine is light in all its parts, occupies but little room, and is easily accessible. Its disadvantages as a marine engine are, its extreme height, rendering it top-heavy, and occasioning great inconvenience, especially in a gale, and its liability to get out of line.

Direct-acting engines are characterized by lightness, and compactness of form. Their defects are, the shortness of stroke and of the connecting rod, which becomes sensible in practice, by an increased wear and tear of brasses and packing and a greater

consumption of oil and tallow, as compared with the side-lever or beam engine.

The advantages of the oscillating engine are, that it consists of few parts, occupies but little space, and is readily accessible for repairs. It has no disadvantages worth mentioning, when well designed and built.

The trunk engine admits of a longer connecting rod than some other forms of the direct-acting engine, and is composed of few parts. But it is very wasteful of steam, as the large mass of metal of the trunk, moving alternately into the atmosphere and cylinder, must condense a portion of the steam. The trunk, also, requires large quantities of oil and tallow.

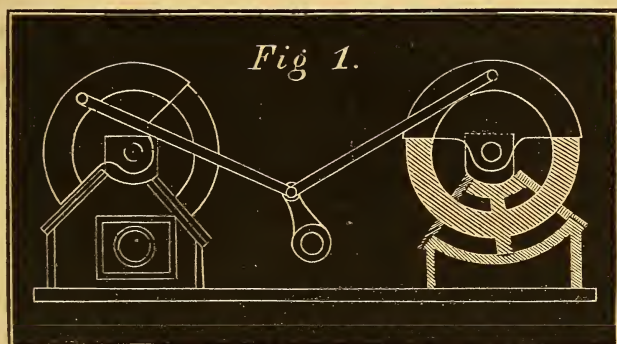
The advantage of a back-acting engine, is the length of its connections. Its disadvantage is excessive weight, as compared with a direct-acting engine.

Rotary engines have not hitherto been so successful as to warrant an extended notice.

Single-acting engines are only employed for pumping, and are not suitable for use in a vessel.

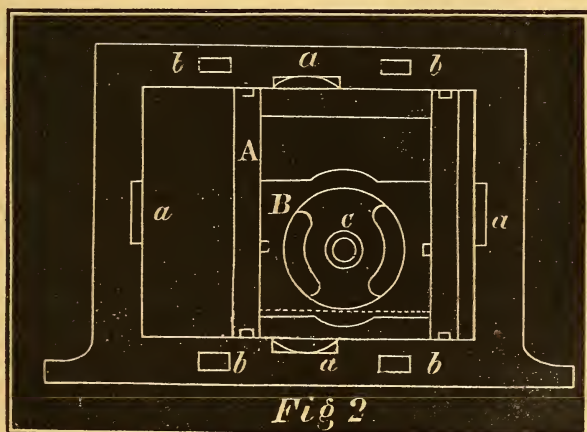
The advantage of geared engines is their slowness of piston speed, diminishing the wear and tear of the working parts, and operating very favorably in the case of the air and feed pumps. But they are larger than direct-acting engines, and besides, we have the weight of, and space occupied by the gearing. Still with all these disadvantages they are very successful, and the authors are of opinion that they are the best design of engines for screw-steamers.

Among the varieties of the steam engine, we will notice Wright's, of which a sketch is given in Fig. 1.



The cylinders are segmental, the piston rods being in the form of rings, as represented.

Root's engine, Fig. 2, has one piston connected



directly to the crank-pin. The pistons are rectangular, and work in a rectangular chamber. The

piston B moves within the piston A and the crank-pin is connected to the former piston, at C. The piston B has a motion up and down, and the piston A a motion alternately to the right and left, so that the resulting motion is circular, *a a a a* are the steam ports, and *b b b b* the exhaust.

§ 2. *Description, advantages and disadvantages of various kinds of Boilers.*

Boilers are either vertical tubular, horizontal tubular, flue, cylindrical, or a combination of these kinds.

The advantages of the vertical tubular boiler are, its economic evaporation, and the facility and completeness with which its heating surfaces can be scaled. Its disadvantages are, that it is often a very difficult matter to discover a leaking tube, and that considerable time is required to plug it after it is found; for the boiler must be entirely blown down and cooled, and the man-holes opened, before the leak can be stopped.

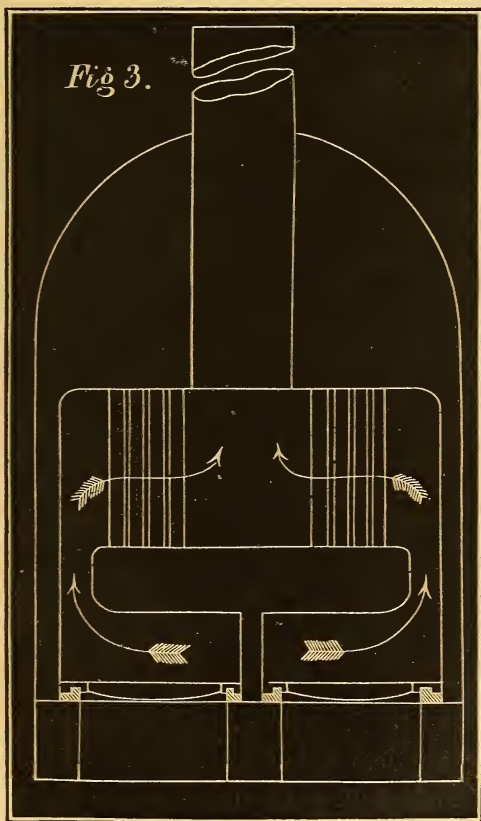
The advantages of the horizontal tubular boiler are, its less cost, and the fact that the tubes can be swept much more easily, rapidly, and completely, than the vertical tubes. If a tube leaks, it can be easily seen and plugged. Its principal disadvantage lies in the impossibility of keeping the entire surface of the tubes free from scale.

The advantages of flue-boilers are, their economy in first cost, repairs and durability. Their disad-

vantages are, the space occupied and their weight, they being at least one-third heavier, and requiring one-third more room than tubular boilers of the same evaporative power.

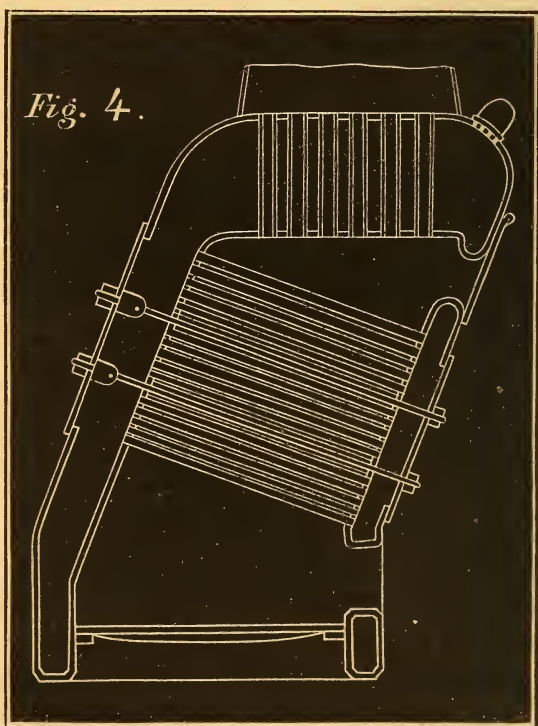
Cylindrical boilers are only used on steamers in the Western rivers, and can scarcely be classed among marine boilers.

Fig. 3 represents the haystack boiler. This is a



round boiler, with vertical tubes and a spherical top. From its shape it requires but little bracing. All the parts are readily accessible for scaling and making repairs, and its evaporative power is very great.

Mr. Dickerson's patent boiler is represented in Fig. 4. Above the furnace the fire passes around inclined tubes, filled with water. In the top of the



boiler are vertical tubes, surrounded with water at the lower ends, and with steam at the upper ends.

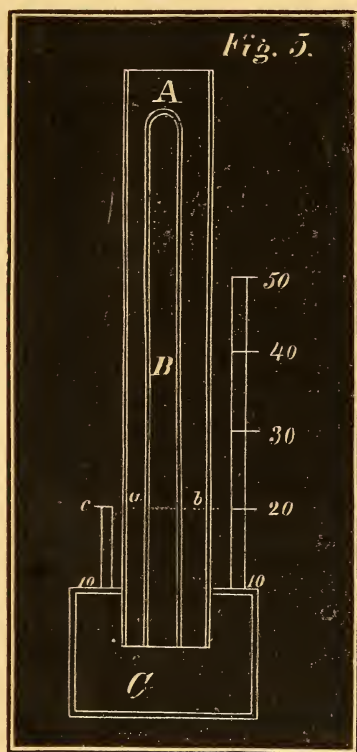
The object of these is to dry and superheat the steam. In the differential tubular boiler, introduced by Chief Engineer A. C. Stimers, U. S. N., the tubes are made of varying sizes, being largest in diameter at the lowest row, and decreasing as they ascend. The object of this is to equalize the temperature of the products of combustion entering the upper and lower tubes.

§ 3. *Appendages to Engines and Boilers.*

Under this head we will class all gauges, oil cups, and the like.

It is usual for every boiler to be provided with a steam-gauge, so that if the stop-valves are closed, the pressure of the steam can be ascertained, and also for the convenience of the fireman and water-tender. Steam-gauges are made in various forms, but they can be put into two general divisions, mercury gauges and mechanical gauges. Of the mechanical gauges, Ashcroft's and Allen's are the most in use. In Ashcroft's gauge the steam acts upon a bent tube, elliptical in section; and in Allen's a conical volute spring of finely tempered steel takes the pressure. The syphon gauge is the most common of the mercurial gauges, and is, doubtless, as good as any. It is well to have one of them attached to the engines or boilers as a test, for mechanical gauges lose their elasticity by use. The manometer gauge

is extensively used, but it is found that the glass tube gets foul very soon. Grimes's patent gauge, represented in Fig. 5, is said to be reliable, and to work very well. B is a closed top glass tube, inside



of A, a larger glass tube open at the top, the bottom of it fitting closely into a vessel of mercury, C. The tube A is filled with alcohol, and its upper end is connected with the steam-pipe. When there is no pressure on the alcohol, the mercury rises in the tube A to *a b*. By a pressure of steam equal to 10 lbs., the mercury is forced out of A to the level of the reservoir, C, and just begins to appear in the tube B. So up to 10 lbs. we read the pressure on the left hand scale, and above that the pressure is indicated on the

right hand scale by the height to which the mercury rises in the tube B.

Besides the glass gauges and gauge-cocks, usually fitted to boilers, percussion gauges are sometimes

attached, to be used when the boilers foam. A percussion gauge consists substantially of a cylinder, into which is fitted a piston, with a projecting rod. It is attached at the water level. If a boiler foams, the idea is to press the piston down, and observe at what point it strikes solid water. Whether any advantage is derived from this instrument is doubtful.

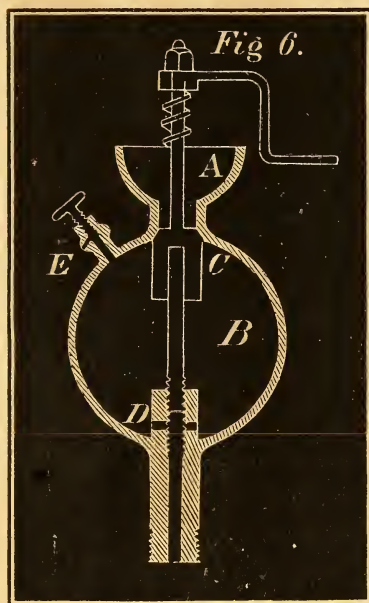
The engines usually have steam and vacuum gauges, the steam-gauges being attached to the main steam-pipe. Gauges of the same general construction as those employed to indicate the pressure of the steam are also used to show the state of the vacuum. Thermometers are generally fitted to the hot wells. In the case of fresh water condensers, two thermometers are necessary, one for the discharge, and the other for the feed-water. Thermometers are also fitted, quite frequently, to show the temperature of the injection water.

Most marine engines have counters to register the number of revolutions. Allen's counter is almost exclusively employed in this country.

A gauge to show the amount of water in the bilge is very useful, and is often attached. When we add the clock, barometer, and engine-room thermometer, the list of appendages is nearly complete.

Engines should be fitted with oil cups on all journals, and also on the steam-chests and cylinder covers. Oil or tallow can readily be introduced into the cylinder of a condensing engine by letting the

pressure of the air force it in, when there is a vacuum in the cylinder. For steam-chests and high pressure engines, the oil cup represented in Fig. 6 is largely used. The reservoirs, A and B, are separated by a valve, C. This is kept against its seat by a spiral spring, and can only be opened by a downward pressure,

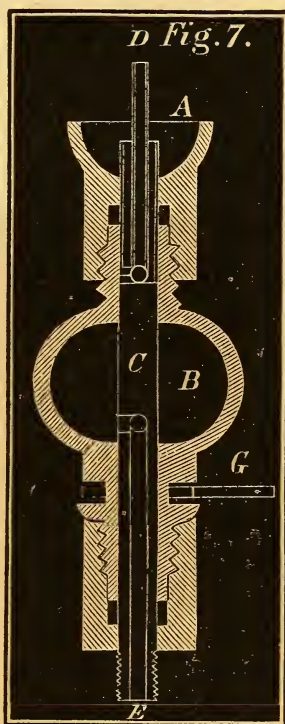


The valve D, when shut, cuts off communication between the steam-chest or cylinder, and the reservoir B. The valve D has a square stem, which fits into a socket in the stem of the valve C. By turning around this upper stem, the valve D is screwed down to its seat, the valve C remaining closed. It will be seen that the valve D must be shut to enable the valve C to be opened. When not in use, all the

parts of the oil cup are as represented in the figure.

The operation is as follows: close the valve D, and open the valve E, to let steam escape from B. Fill A with oil, and open the valve C, to let the oil run down into the reservoir B. Then close E, and open D, when the oil will run down into the cylinder or steam-chest.

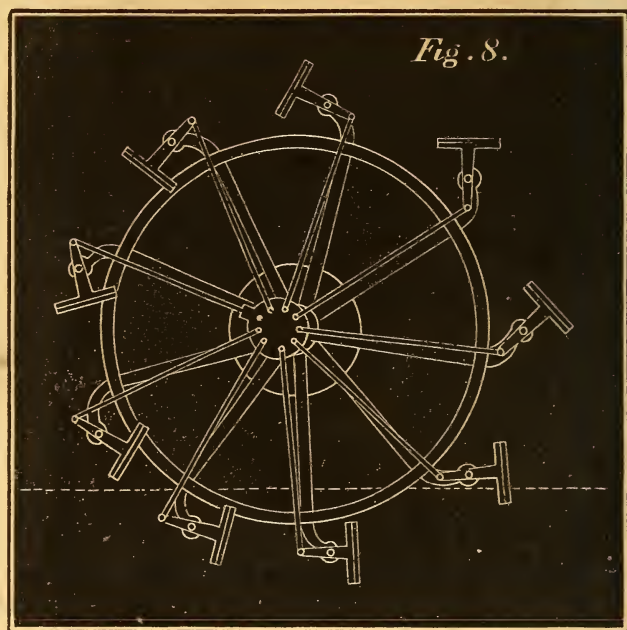
Fogle's oil cup, sketched in Fig. 7, has no valves or cocks. The cup slides up and down on the tube C, by raising or lowering the handle G. Suppose the reservoir A to be filled with oil. By raising the cup, the steam escapes from B through the pipe D, and the oil runs into B. On returning the cup to its original position, the oil will run into the cylinder through the pipe E



§ 4. *The Paddle-Wheel.*

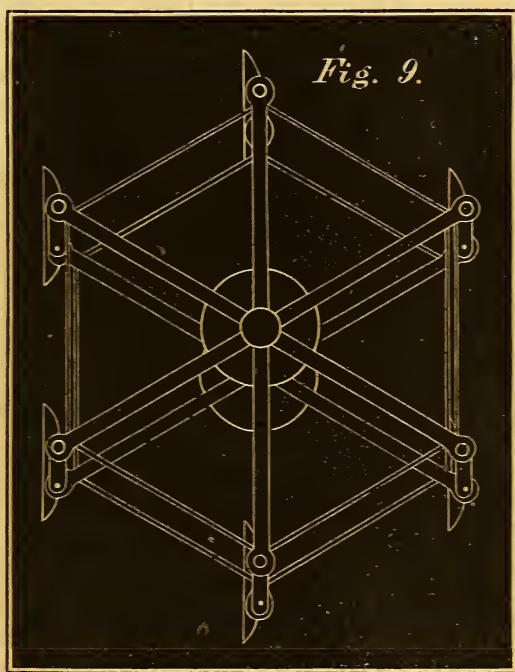
Although the plans for applying the power of the engines to propel ships through the water have been numerous and varied, the only two that have stood the test of time are paddle-wheels and screw propellers. Paddle-wheels are of two general kinds,

radial and feathering wheels. In the case of the radial wheel, the floats enter and leave the water obliquely, only being vertical in the centre of the arc of immersion. In the feathering wheel the floats are governed by mechanism, which causes them to enter and leave the water in a position perpendicular to the direction of their motion. Fig. 8 is a sketch of a feathering wheel, which will show the arrangement by which the floats are governed.



The Manley paddle-wheel, which has lately been the subject of many experiments, and is considered a very successful variety of the feathering wheel, is

represented in Fig. 9. This wheel has only six or eight floats. Each float is secured to a rock shaft, to which a crank is attached. The feathering mechanism is a frame, eccentric to the main shaft, connected with each of the cranks by an arm. Each



float is secured to the rock shaft below the centre, so as to divide the pressure on the float equally between the feathering mechanism and the adjacent side frame of the wheel.

The following is an extract from the pamphlet issued by the Manley Paddle-Wheel Company :

“This wheel is the first machine for marine propulsion, which, by its action and application of power, has imitated the Indian’s paddle, and has conformed to the first great principle necessary to be observed in propelling a vessel through the water, by obtaining the proper resistance for the power upon the water. The Indian reaches forward and drops the blade of his paddle into the water vertically, and instantaneously exerts his force in a direction opposite to that in which he wishes the boat to move, and perpendicular to the line of floatation, then withdraws the blade entirely from the water and repeats the operation, at all times keeping his paddle vertical while it is in the water. * * * * This wheel does for the great steamship what the Indian’s paddle does for his boat, and even in greater perfection. It drops a paddle into undisturbed water, forces it backward or forward, as the case may be, in a direction exactly perpendicular to the line of floatation, and as it is being withdrawn from the water, another paddle is entering far ahead, and grasping resistance entirely unused by the preceding paddle, and this operation is certain and constant while the power is applied. There is no tearing of the water, no paddle following water which has been put in motion by a fellow paddle, no displacing of water, either upward or downward.”

There have been numerous devices for causing the floats of the radial wheel to enter the water with as little resistance as possible, and on leaving the water

not to lift any of it. The principles on which these wheels are constructed appear to be very good, but they have not yet displaced the common flat float.

Although the feathering wheel produces more useful effect, with the same application of power, than the radial wheel, there are many practical objections to its use; the most prominent of which are the increased first cost, the excessive weight, and the frequent overhauling that they require.

The action of a radial wheel in propelling a vessel resembles that of the wheel of a carriage. While the wheels of a carriage, however, propel the carriage the whole distance due to their rolling motion, paddle wheels do not propel a vessel a distance due to their velocity at the circumference. But the velocity of some circle within the circumference will be equal to the speed of the vessel, and we call this circle the *rolling circle*.

EXAMPLE.—Suppose a side-wheel steamer is propelled through the water at the rate of 12 statute miles an hour, the engines making 19 revolutions per minute; what is the diameter of the rolling circle?

The distance passed over by the vessel in an hour is

$$5280 \times 12 = 63360.$$

Now the wheels make $19 \times 60 = 1140$ revolutions per hour, and the circumference that will pass over 63360 feet in 1140 revolutions is $63360 \div 1140 = 55.58$ feet. The diameter corresponding to this

circumference is $55.58 \div 3.1416 = 17.69$ feet, which is the diameter of the rolling circle.

From the fact that $5280 \div 60 = 88$, is a constant number to be introduced into all calculations for the diameter of the rolling circle, we can give the following rule. Multiply the speed of the vessel in miles per hour by 88, and divide this product by 3.1416 times the number of revolutions of the wheels per minute. This will give the diameter of the rolling circle. By this rule the solution of the preceding example will be,

$(12 \times 88) \div (19 \times 3.1416) = 17.69$ feet, the diameter of the rolling circle.

In this rule the speed of the vessel is given in statute miles, for the sake of having the constant quantity, 88, a whole number. When the speed is given in nautical miles, we have only to multiply by 1.15, and the result will be the speed in statute miles.

That point in each float of a paddle-wheel at which the whole pressure acting on the float being applied would produce the same effect as when acting on the whole float, is called the *centre of pressure*. For a radial wheel we usually take the centre of pressure at about $\frac{1}{3}$ of the width of the float from the bottom. This is on account of the greater velocity of the outer extremity of the float, causing the resistance at the circumference to be greater than at the inner extremity. The following empirical formula is also frequently employed to find the

position of the centre of pressure in a radial wheel. Subtract the diameter of the rolling circle from the diameter of the paddle-wheel, and add half the difference to the width of the float; raise the sum of these two numbers to the fourth power, and divide the result by four times the width of the float; find the cube root of the quotient, then subtract from this root half the difference between the diameters of the wheel and rolling circle; the remainder will be the required quantity, or the perpendicular distance of the centre of pressure from the inner extremity of the float. There is one thing to be remembered in using this rule, that the rolling circle must have a constant diameter. The average diameter of the rolling circle can easily be obtained by experiment for any particular wheel, and then it is fixed. With this understanding, the rule is tolerably accurate.

EXAMPLE. — Find the position of the centre of pressure of a radial wheel, from the following data: diameter of wheel, 26 feet; width of float, 30 inches; revolutions of engines per minute, 18; speed of vessel in knots per hour, 10.

$10 \times 1.15 = 11.5$, speed of vessel in statute miles;
 $(11.5 \times 88) \div (3.1416 \times 18) = 17.89$, diameter of rolling circle.

Now we are ready to apply the rule. Half the difference of the diameters of the wheel and rolling circle is

$$26 - 17.89 \div 2 = 4.055.$$

The width of the float being 2.5 feet, we shall have

$$(4.055 + 2.5)^4 \div (2.5 \times 4) = 184.625,$$

cube root of 184.625 = 5.694.

5.694 — 4.055 = 1.639 = 1 foot, $7\frac{7}{8}$ inches, distance of centre of pressure below top of float.

It must be observed, that as a float enters and leaves the water, it is only partially immersed, and as we wish to find the mean centre of pressure, we must consider this in making our calculation. Let us divide the arc of immersion into a number of equal parts, which will represent different positions of a float in its passage through the water. When entering, it will require to be about half immersed before it will experience any decided resistance. Suppose the number of divisions of the arc to be 25; then for the first and last positions of the float, we must calculate the centre of pressure for half of the float; for the other 23 positions we make the calculation for an immersed float. For the immersed float the centre of pressure is $30 - 19\frac{1}{2} = 10\frac{1}{2}$ inches from the lower extremity. For the half immersed float, it will be sufficiently accurate to call the centre of pressure $10\frac{1}{2} \div 2 = 5\frac{3}{16}$ inches from the lower extremity. The mean centre of pressure will then be $(10\frac{1}{2} \times 23 + 5\frac{3}{16} \times 2) \div 25 = 9\frac{9}{16}$ inches from lower extremity of float.

If we use the other empirical rule, that the centre of pressure is $\frac{1}{3}$ of the width of the float from the lower extremity, we shall have $30 \div 3 = 10$ inches,

as the distance of the centre of pressure from the lower extremity of the immersed float, and $15 \div 3 = 5$ inches, as the distance from the lower extremity of the half immersed float. The position of the mean centre of pressure will then be

$(10 \times 23 + 5 \times 2) \div 25 = 9\frac{3}{2}$ inches from lower extremity of float. A mean of these two results give us $9\frac{3}{4}$ inches as the position of the mean centre of pressure.

For a feathering wheel the position of the centre of pressure below the surface of the water, for the immersed float, is found by taking $\frac{2}{3}$ of the difference of the cubes of the immersions of the upper and lower extremities of the float, divided by the difference of the squares of these immersions. For the half immersed float, the centre of pressure is $\frac{1}{3}$ of the immersed width from the lower extremity of the float.

EXAMPLE.—Find the centre of pressure of a feathering wheel, having the same diameter and width of float as the radial wheel in the preceding example.

Divide the arc of immersion into 25 equal parts, as before, and find the immersion of the lower extremity of the float in the 23 intermediate positions. From these different distances we can get the mean immersion. Let us suppose the operation completed, and that we find the mean immersion to be 61.3 inches from the surface of the water. The mean immersion of the upper extremity of the float in these intermediate positions will be $61.3 - 30 = 31.3$

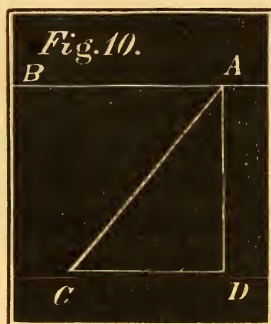
inches. Hence the mean centre of pressure for the immersed float will be

$\frac{2}{3}$ of $(61.3^3 - 31.3^3) \div (61.3^2 - 31.3^2) = 47.82$ inches from the surface of the water, or $61.3 - 47.82 = 13.48$ inches from the lower extremity of the float. For the half immersed float the centre of pressure is $15 \div 3 = 5$ inches from the lower extremity. Hence the mean centre of pressure is

$(13.48 \times 23 + 5 \times 2) \div 25 = 12\frac{3}{8}$ inches from the lower extremity of the float.

In the case of the radial wheel, part of the power applied is lost by oblique action, and part by slip. We will show the method of determining these losses. Let us first consider the loss by oblique action.

Let A C (Fig. 10) represent the position of a float of a radial wheel, making an angle, B A C, with the surface of the water in which it is immersed. Now the float, in passing through the water, has a pressure



in proportion to its depth, A C, and produces an effect varying directly as the pressure, so that the power exerted varies as the square of A C. But on account of the float passing through the water obliquely, the only power producing useful effect will be that developed by the vertical component (A D) of A C. The power developed by the horizontal component, C D, acts in forcing the water downward, if the float is moving to the right,

and lifts the water, if moving to the left; therefore all this power is lost. If we make AC equal to one, then by trigonometry CD , the component, producing no useful effect, is equal to the sine of the angle CAD . This gives us a very simple method of determining the loss by oblique action. If the power developed by AC is one, the power lost by oblique action, since it varies as the square of the arm producing pressure, is equal to the square of the sine of the angle CAD . Thus, let the angle CAD equal 45° . The sine of 45° is .70711, and the square of this is .5, so that .5 or 50 per cent. of the power applied to the float is lost, when it makes an angle of 45° with a line perpendicular to the surface of the water, and only $1 - .5 = .5$, or 50 per cent. of the power applied is effective in propelling the vessel. If the angle CAD is 30° , its sine is .5, and the loss by oblique action, or the square of the sine, is .25, or 25 per cent. of the power applied to the float, and $100 - 25 = 75$ per cent., produces useful effect. If the float AC coincides with the vertical component AD , as it will when the float is in its lowest position, there will be no loss from oblique action, as will be at once apparent. Now we see that the loss from oblique action varies at every position of the float. Hence we must find the mean of the losses at various positions.

EXAMPLE.—Let us have a radial wheel, whose floats are immersed to such a depth that the angle formed by the intersection of the positions of the

entering and emerging floats, at the centre of the wheel, is 100° , required the loss by oblique action.

We will divide one-half of the immersed arc of the wheel into any number of equal parts, and draw lines from each point of division to the centre of the wheel. We shall thus determine various positions of the immersed float. The positions in the other half of the immersed arc would be exactly similar, and we shall not need them in the calculation. Now find the per cent. of loss by oblique action at each of these positions of the float, multiply it by 2 for the whole arc, since we only made the calculation for one-half, and take the mean, which will give the mean per cent. of loss. We will find the per cent. of loss for every increase of 2° in the angle between the float and perpendicular. At the centre of the arc, where the float is vertical, there is no loss. When the float makes an angle of 2° with the vertical, the loss is the square of the sine of 2° , or .003045, which equals .3 per cent. of the power applied. When the angle of the float with the vertical line is 4° , the loss equals the square of the sine of 4° , or .004804, .48 per cent. of the power applied. Continuing the operation for every angle, increasing by 2° up to 50° , we have

$$(0 + .3 + .48 + 1.09 + 1.93 + 3.01 + 4.32 + 5.85 + 7.59 + 9.54 + 11.69 + 14.11 + 16.54 + 19.22 + 22.05 + 25 + 28 + 31.27 + 34.54 + 37.9 + 41.32 + 44.77 + 48.24 + 51.73 + 55.22 + 58.67) \times 2 = 1148.4.$$

Since we have made the calculation in 25 different

positions of the float, exclusive of the vertical position, or at $25 + 1 + 25 = 51$ positions for the whole immersed arc,

$1148.4 \div 51 = 22.517$ per cent. of power lost by oblique action.

The following rule is derived by experiment, and is found to give the result more accurately than the preceding method. Multiply the sine of the angle of immersion, or the angle made by the extreme positions of the immersed floats with each other, by 25, and subtract the product from 50. The remainder is the per cent. of loss by oblique action.

In the preceding example, the angle of immersion is 100° , and the sine of 100° is .98481. Hence the per cent. of loss by oblique action is,

$$50 - (25 \times .98481) = 25.379.$$

By this rule the per cent. of loss is slightly greater than by the first method; but if the divisions of the arc had been small enough in the first case, the two results would have coincided more nearly, for the rule just enunciated is merely a method of finding the per cent. of loss, when the divisions of the immersed arc are exceedingly small.

As the per cent. of loss by oblique action depends directly on the angle of immersion, it is evident that this per cent. will be greater, the greater the immersion for wheels having the same diameter.

Let us now consider the loss of effect from slip. Suppose a steamer has radial wheels with a diameter of 26 feet; that the width of the floats is 30 inches;

that the vessel has a speed of 12 statute miles per hour, and that the wheels make 18 revolutions per minute; what is the per cent. of slip?

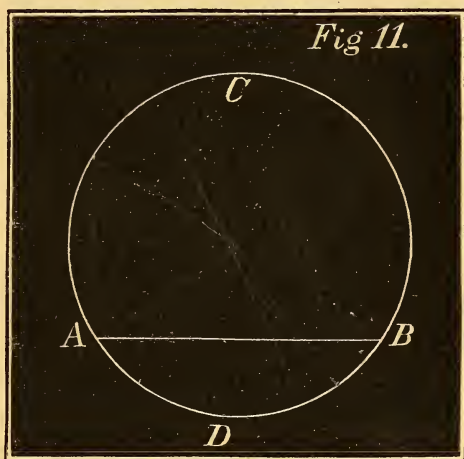
By the method shown in a previous part of this article, we find the diameter of the centre of pressure of the wheel to be 24 feet, $4\frac{1}{2}$ inches. The difference between the distance passed over by a wheel of this diameter and the speed of the vessel, is the slip. In the example under consideration, the vessel passes over $12 \times 5280 = 63360$ feet per hour, while the speed due to the velocity of the centre of pressure is $24.3958 \times 3.1416 \times 18 \times 60 = 82749.6$. The slip, therefore, is $82749.6 - 63360 = 19389.6$ feet, or $(19389.6 \times 100) \div 82749.6 = 23.4$ per cent. of the speed due to the wheels.

This 23.4 per cent. is not the per cent. of loss from slip, since there can be no loss from slip, for the component of the float that produces no useful effect. The power that exerts no propelling force, can have no slip, since slip has a direct relation to the speed with which the floats force a vessel through the water. Now we have already found the loss by oblique action to be 25.37 per cent. of the power applied to the wheels. Therefore, only $100 - 25.37 = 74.63$ per cent. of the whole power produces propelling effect. So we see that the loss of effect from slip is 23.4 per cent. of the power producing useful effect, or $74.63 \times .234 = 17.46$ per cent. of the whole power applied to the wheels.

Summing up the losses of effect, we have 100 —

$(17.46 + 25.37) = 57.17$ per cent. of the whole power applied, producing useful effect, and $17.46 + 25.37 = 42.83$ per cent. of the power, lost by slip and oblique action.

In the case of a feathering wheel, there is a loss of useful effect, from three causes: friction of the mechanism for feathering the floats, slip, and drag, caused by the vessel going faster than the entering and leaving float. Suppose A C B D, Fig. 11, to be the circle described by the centre of pressure of a feathering float. Now if there is no slip, the float, which is vertical all the time, will propel the vessel the distance A D B, while travelling the horizontal



distance, A B. Thus, we shall have the vessel going through the water faster than the floats, and the latter will therefore be dragged, and there will be a per cent. of loss, in proportion to the difference between A D B, and A B. But if there is slip, the loss from drag will be the difference between A B, and A D B diminished by the slip. In actual practice there will be no drag, unless the wheel has very

great immersion, or an exceedingly small slip. If we take a feathering wheel, having the same diameter of centre of pressure, the same immersion, size of floats, and per cent. of slip, as the radial wheel previously considered, we shall find that instead of any drag existing, the floats will move faster horizontally, than the vessel travels. The chord of the immersed arc, or the distance passed over by a float horizontally in this case, is 18.67 feet. The arc of immersion, or the distance passed over by the centre of pressure, while the float moves 18.67 feet horizontally, is 21.27 feet. So if there were no slip, the loss from drag would be $21.27 - 18.67 = 2.6$ feet, or $2.6 \times 100 \div 21.27 = 12.3$ per cent. But according to our supposition, there is 23.4 per cent. of slip; so that the vessel only travels $21.27 - (21.27 \times .234) = 15.19$ feet, while the float travels horizontally, 18.67 feet. Therefore, the float moves horizontally, $18.67 - 15.19 = 3.48$, or $3.48 \times 100 \div 18.67 = 18.6$ per cent. faster than the ship travels.

If the friction of the feathering mechanism is not considered, the total loss of effect in the present case, is 23.4 per cent., which is $42.83 - 23.4 = 19.43$ per cent. less than in the radial wheel.

The friction of the feathering mechanism can only be determined by experiment. In the examples under consideration, as both wheels have the same per cent. of slip, and the feathering wheel utilizes 19.43 per cent. more power than the radial, it follows that, all other things being equal, a vessel fitted with

feathering wheels should go just as fast as a vessel fitted with radial wheels, with an expenditure of 19.43 per cent. less power. Thus, if the engines of the latter ship exerted 1000 horse power to produce a speed of 10 knots, the engines of the vessel fitted with the feathering wheels, should only exert $1000 - (1000 \times .1943) = 805.7$ horse power, to produce the same speed. Suppose, however, that the actual horse power required in the latter case was 900. Then we have $900 - 805.7 = 94.3$ horse power, or $94.3 \times 100 \div 900 = 10.5$ per cent. of the whole power developed by the engines, expended in overcoming the friction of the feathering mechanism. This gives us $100 - 10.5 = 89.5$ per cent. of the whole power, transmitted to the wheels. Here we have a loss of $89.5 \times .234 = 20.94$ per cent. from slip; so that the total loss of effect in the feathering wheel, is $20.94 + 10.5 = 31.44$ per cent. of the power transmitted. Hence, the gain over the radial wheel is $42.83 - 31.44 = 11.39$ per cent.

§ 5. *The Screw Propeller.*

A screw is generated by the revolution of a line or surface, called the *generatrix*, around a cylinder, the generatrix passing through the axis of the cylinder, and advancing along the axis as it revolves.

If the axial motion has a constant ratio with the circular motion, a true screw is generated; but if the axial motion is continually increasing, while the circular motion is constant, the result is a screw with an expanding pitch.

The *pitch* of a screw is the axial distance travelled by the generatrix, while it makes one revolution around the cylinder.

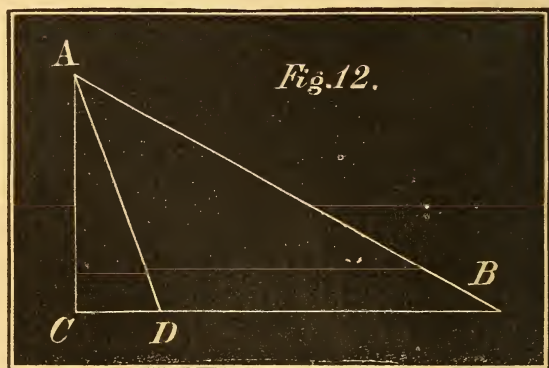
In the case of a screw propeller, the hub takes the place of the cylinder, and the blades are threads of screws, where only a fraction of the pitch is employed. The blades are supposed to be generated by lines, and then the proper thickness is put on.

Now suppose that we generate a screw thread with a line, and that the generatrix makes one revolution.

Suppose, also, that the outer extremity of the generating line traces its path on the surface of a cylinder, and that the cylinder be then developed, so as to coincide with a plane surface.

In the first place, let us generate a true screw.

If we suppose the generating line to start from the point A, Fig. 12, when its path is developed, it will



appear as the straight line A B; for it has travelled

in an axial direction, the distance $A C$, and in a circular direction, the distance $C B$, with a constant motion. So we see that $A C$ represents the pitch, and $A B$ the thread of the screw.

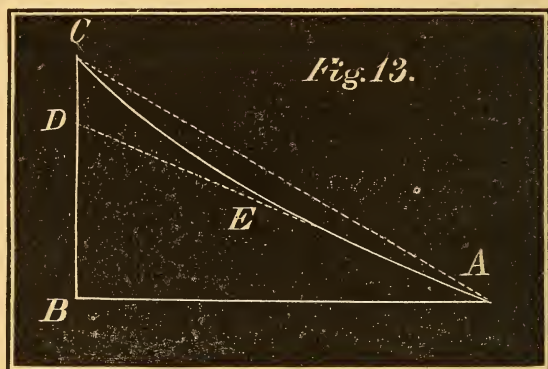
The angle $B A C$, is called the *angle of the screw*, and it is evident that this angle is constant, whether the whole pitch, or only a fraction, is employed.

This angle, $B A C$, although called the angle of the screw, is only the angle at the periphery. Suppose, while the outer extremity of the generatrix moves around the axis, a distance $C B$, the other extremity, or the end that touches the cylinder, moves a circular distance $C D$. Then the path described by this extremity of the generatrix, since it moves the same distance $A C$, in an axial direction, is evidently $A D$. So we have another angle $D A C$, of the blade, and this is called the *angle at the hub*.

It will readily be seen that the angles of the blade vary at every point of the circumference, and the angle $B A C$, is only called the angle of the screw from the fact of its being used in the construction of a propeller, as will be seen hereafter.

Now let us take the case of a screw with an expanding pitch. The generatrix starts from the point A , Fig. 13, with a pitch $D B$, which increases to $C B$, by the time the generatrix has made one revolution. We see that at the commencement of the motion of the generatrix, it takes the path $A D$, and at the end of one revolution, takes the path $A C$, so that a curved line, $A E C$, drawn tangent to

these two paths, will represent the course of the generatrix.



A C B is now called the angle of the screw, and is used as a guide for the sweep, in constructing the propeller.

In this form of expanding pitch, we say that the pitch expands from forward to after part of blade, or vice versa. The pitch may also expand from hub to periphery, or the reverse. All such screws are termed irregular.

The advantage claimed for a propeller with pitch expanding from forward to after part of blade, is as follows: The part of the blade entering the water, acts upon water at rest, while the part of the blade following, acts upon water set in motion by the first part of the blade, and its pitch is increased, so as to encounter a resistance equal to that of the entering edge of the blade.

Whether, after the propeller has made one revolution, and all parts of the blade have set the surrounding water in motion, the gain from this expanding pitch is as decided as has been alleged, is a question.

The designers of propellers, whose pitch expands from hub to periphery, claim, and with very good reason, that the part of the blade near the hub is of very little service in propelling the vessel, and that it is a gain to make this part move through the water with as little resistance as possible. But this can be accomplished, and frequently is, by cutting away that portion of the blade nearest the hub, and increasing the surface at the periphery.

To still further diminish the prejudicial resistance, the hub is frequently made spherical. Sometimes it is made very large, so as to take the place of that portion of the blade which has but little propelling effect.

In view of the facts that all these modifications of the propeller give good results, and that various builders, each designing propellers with distinct features, have been successful in the results obtained from their designs, it seems impossible to give rules and formulæ by which the best propeller may be constructed.

The authors of this work incline to the opinion that a true screw can be constructed to produce as good results as any other.

We will now complete the definitions connected

with the propeller, and at the same time take into consideration a few general principles of proportioning the parts.

The *slip* of a propeller is the difference between the actual distance travelled by the ship, and the distance it should have travelled by the motion of the propeller.

Thus: suppose the propeller to have a pitch of 25 feet, and to make 50 revolutions per minute; then the distance in knots it should move in an hour is

$$(50 \times 60 \times 25) \div 6027 = 12.4.$$

But the ship, we suppose, has an actual speed of 11 knots, consequently,

$$(12.4 - 11) = 1.4 \text{ knots} = \text{slip, or,}$$

$$(1.4 \times 100) \div 12.4 = 11.3 \text{ per cent. slip.}$$

We see that the slip is caused by the propeller working in a yielding medium, so we can define the slip of a propeller as the motion of the water astern. In designing a propeller, we can only allow for the slip under favorable circumstances. We know, by experience, that in good weather the slip of a well-designed propeller is from 10 to 15 per cent. But in the case of a strong head wind and sea, while the revolutions of the propeller remain unchanged, the speed of the vessel is materially decreased. This is so, from the fact of water being a yielding medium, and from the manner in which the blades enter the water, so that, when a head wind and sea prevail, the resistance to the motion of the propeller is not

increased, but there is more motion of the water astern, in direct proportion to the increased resistance to the passage of the ship through the water.

A propeller with a small pitch has its slip slightly reduced, particularly in the case of adverse winds and seas, from the fact that the resistance to its motion is more in the direction of its propelling face than when the pitch is greater. But when a small pitch is employed, an increased number of revolutions must be made, to keep up the speed of the vessel, and there is a practical limit to this.

When a ship has a greater speed than is due to the propeller, we say that the propeller has *negative slip*. Such a case may occur with a fair wind, and all sail set, but in a calm its occurrence seems rather improbable. Still, such a result might be effected by the springing or twisting of the blades, thereby causing an increase of pitch. In the generality of screw steamers, however, we will venture to assert that negative slip is a thing unknown.

Propellers are constructed with the number of blades varying from two to four, and sometimes exceeding the latter number. The number should not be so great that the amount of water between two contiguous blades would be reduced so as to lessen the resistance.

Hence small propellers, by reason of their small surface, are usually constructed with four blades, while large ones rarely have more than three.

The *area of the screw's disc* is the area of a circle

having the same diameter as the propeller. It is evident, that if the propeller were to make one revolution, and the surface of the blades were then to be projected upon a plane surface perpendicular to the axis, this projection would be equal to the area of the screw's disc. Now, as the propelling force of the screw is only exerted in the direction of the axis, this area represents the thrusting surface of the propeller. The thrust is usually ascertained by the application of a dynamometer to the shaft.

The theoretical thrust is ascertained as follows: If the piston and propeller had an equal speed, then the theoretical thrust would be the pressure on the piston. But as this is seldom the case, we find the speed of the piston in feet per minute, and also the speed of the propeller, in an axial direction, in the same time. Then the speed of the piston, divided by that of the propeller, is the ratio of the two speeds. Multiply this by the pressure on the piston, and we have the theoretical thrust in pounds.

EXAMPLE.—Required to find the theoretical thrust of a propeller, driven by a single direct-acting engine, having a piston 60 inches in diameter, and a stroke of 3 feet. Let the effective pressure of steam be 25 pounds, the number of revolutions 55, and the pitch of the propeller, 22 feet.

$2827.4 \times 25 = 70685 =$ pressure on piston, in pounds.

$2 \times 3 \times 55 = 330 =$ speed of piston, in ft. per minute.

$22 \times 55 = 1210 =$ speed of propeller, in ft. per minute.

$330 \div 1210 = \frac{3}{11} =$ ratio of speeds.

$70685 \times \frac{3}{11} = 19259.5 = \text{thrust of propeller, in pounds.}$

The dynamometer thrust will be less than this. The difference between the two shows the pressure required to overcome friction and other prejudicial resistances.

It is often necessary to measure a propeller for purposes of construction, and it is also useful to do so for further reference. We will therefore explain the method.

The object is to obtain the development of the thread of the screw, and form a triangle, as shown in Fig. 12. (The measurements of the hub and diameter are so simple as to require no explanation.)

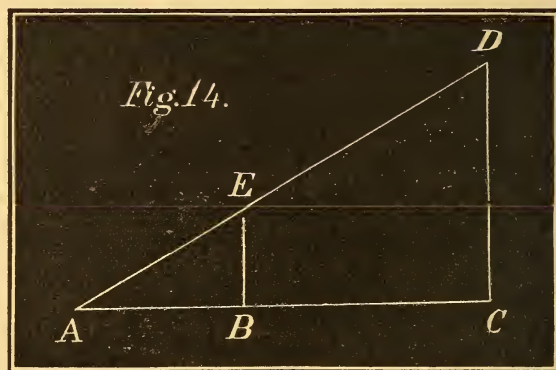
As the blade at its extremity is frequently rounded off on the corners, it is better to assume a point a little within the circumference, to make the measurement.

Having assumed a point, measure its distance from the centre, and with a piece of chalk draw a line to represent the helix described by the generatrix, at that distance from the centre. This is the line that we wish to develope. From one extremity of this helix, hold a straight-edge parallel to the axis of the propeller, and from the other extremity, hold a straight-edge perpendicular to the first. Measure the lengths of these two straight-edges, between the points of their intersection and the extremities of the helix.

Our measurements are then complete. The first distance is the fraction of the pitch, or the motion of

the generatrix in an axial direction, and the second is the fraction of the circumference, or the motion of the generatrix in a circular direction. By laying down these two distances at right angles to, and intersecting each other, and connecting their extremities, we have the thread of the blade, and the triangle is complete.

Now we must find the whole pitch, having the fraction given. Ascertain what is the circumference described at the distance from the centre at which we assumed our point, and then make the following proportion : *The measured fraction of the circumference :*



the whole circumference :: the measured fraction of the pitch : the whole pitch, or, Fig. 14, as A B : A C :: B E : C D.

EXAMPLE. — Suppose, that on taking measurements in the manner indicated, we find the fraction of the pitch to be 18 inches, the fraction of the circumference, 3 feet, and that we have made the measure-

ments 5 feet from the centre of the propeller. Now the circumference whose radius is 5 feet, is 31.41; hence,

As 3 : 31.41 :: 1.5 : 15.7 feet, whole pitch.

In the preceding discussion, we have assumed that the propeller we were measuring, was a true screw. But the principle of the measurements is the same in all cases, and it only remains to show the methods of determining whether the propeller has an expanding pitch.

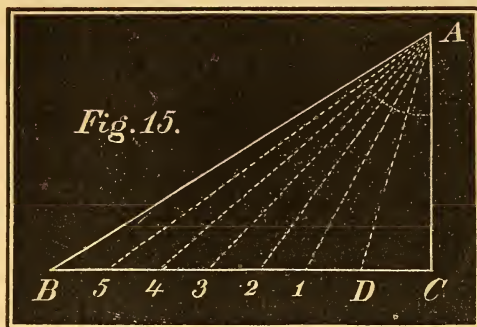
Take two measurements for the pitch, one near the hub, and the other near the periphery. That will show whether the pitch expands from hub to periphery, or is constant. Then divide the helix that is drawn near the periphery, into two equal parts, and take the extremities of each of these parts as the points at which to set the straight-edges. We shall thus determine whether the pitch expands from forward to after part of blade.

In all cases where the pitch of a propeller varies, we must find it at various points of the blade, and take the mean to use in calculations where the pitch is introduced.

We will now explain the method of laying down and constructing a propeller. Let us first take the case of a true screw. We will give the propeller four blades, and suppose its diameter to be 5 feet, and its pitch 10 feet.

The first thing to be done, is to make the angle

of the blade. In Fig. 15, we lay off B C, equal to



the circumference of the wheel, and A C, at right angles to B C, equal to the pitch. Then A B, represents the thread of the screw, and the angle B A

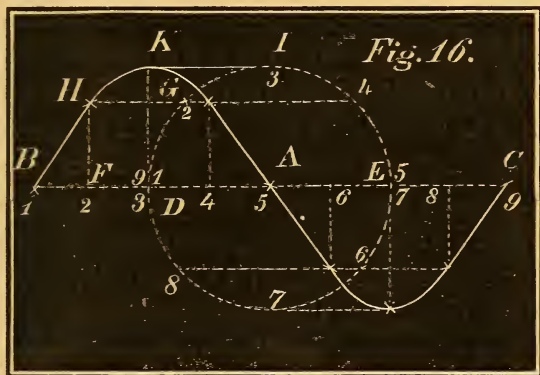
C, is the angle required.

Next, lay off C D, equal to the circumference of the hub, and D A C is the angle at the hub. (We suppose the hub to have a diameter of 12 inches at the ends, increased to fourteen inches in the centre. Its length is 12 inches). Now A D is the development of the helix described by one extremity of the generatrix, and A B, the development of the helix described by the other extremity.

All the intermediate points of the generatrix will describe helices, whose developments will start from A., and run down to given points in D B, the development of the circumference. We will represent such helices as we shall use, at regular intervals of the circumference. Hence, divide the line D B into any number of equal parts, and draw lines from the points of division to the point A. These lines will be the development of the helices required.

In this way we construct the developments of five

intermediate helices, A 1, A 2, etc. When we draw the plan of one of the blades, it will be necessary to draw the helices undeveloped; and we will show the manner of laying one down. In Fig. 16 we desire to construct the helix described by the outer extremity of the generatrix. B C represents the pitch, 10 feet, and the circle whose centre is A, the centre of the pitch, and whose diameter is D E, the diameter of the propeller, represents the circular distance



travelled by the extreme point of the generatrix, while it passes over the axial distance, B C. So if we divide B C into any number of equal parts, and the circle into the same number, we can find points of the helix. Thus, when the extreme point of the generatrix has passed over the axial distance B F, it has gone in a circular direction, the distance D G, and hence the actual position of this point is H.

Similarly, when the point has gone in an axial

direction, the distance B D, and in a circular direction, the distance D G I, it will appear at K.

Having found all the points, draw a curve through them, and this will be the helix described by the generatrix at the periphery.

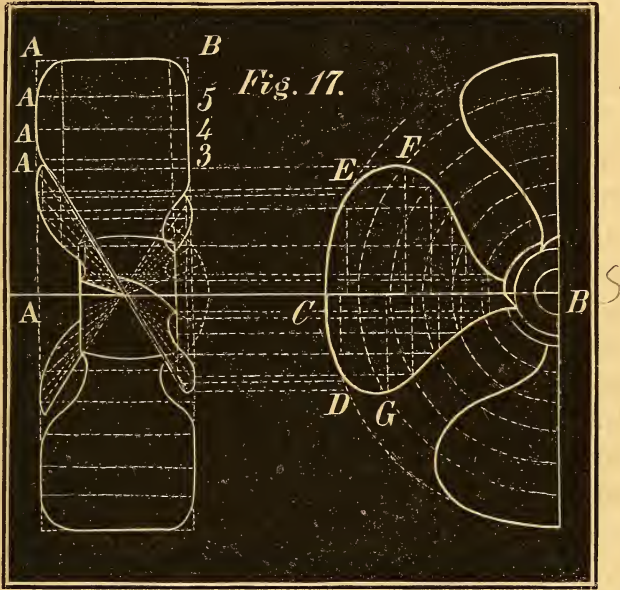
We might next draw the circle whose diameter equals that of the hub, and construct the helix described by the generatrix at the hub; then divide the space between these circles into five equal parts, and construct the helices whose developments are A 1, A 2, etc. But it will be found that such parts of these helices as we shall use are practically straight lines, making angles with the line B C equal to 1 A C, 2 A C, etc. This is equally true of the helices of the periphery and hub. So we can at once lay off these helices to construct the plan of the blades.

In Fig. 17 draw the side elevation of the hub according to the measurements already given. Draw also the centre line A B.

This has the same relative position as the line A C, Fig. 15, or B C, Fig. 16. Therefore, if from the centre of the hub we lay off lines making angles with A B, respectively equal to D A C, 1 A C, 2 A C, etc., we shall represent the helices of which A D, A 1, A 2, etc., are the developments.

We will next draw the side elevation of the blades. The helices will here appear as straight lines, parallel to the axis. They are indicated in the figure. We must determine how much the blades shall project beyond the ends of the hub. We will suppose that

they project 2 inches on the forward end, and 5 inches on the after end.



Having thus fixed the limits of the blades, put in the side elevation to suit the fancy. This done, the form of the blade is fixed. Now observe the points where the boundaries of the side elevation cut the helices A B, A 5, A 4, etc., and project these points until they cut the corresponding helices laid down for the construction of the plan. Join the points so found by a curved line.

It will be seen that the whole thickness of the blade at the periphery, and part of the thickness at the hub, are visible in the plan. Having put these in, the plan is complete.

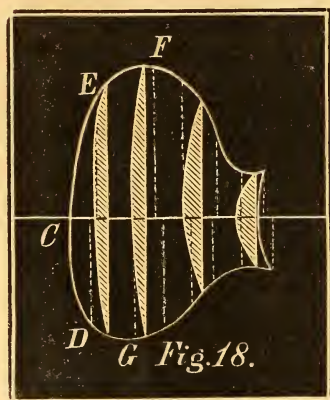
Then find the points necessary to construct the plan of the opposite blade, and draw as much of that as is visible.

In the end elevation of the propeller all the helices will appear as circles.

Draw the end elevation of the hub, and put in the helices, to correspond with those in the preceding views. Now project over points in the plan of the blade to corresponding helices in the end elevation. Connect these points by a curved line, and we have the end elevation of one blade.

By transferring these points, we can construct the remaining blades.

It now remains to find the development of one blade, and to show the thickness at various points. The helices that are represented as circles in the end elevation will evidently appear as ellipses in the development. The part E C D, for instance, will develop as an ellipse, the points E and D of which will be situated from the point C in a vertical direction, the distance of their respective versed sines. So in Fig. 18 we transfer these points, D and E, at the proper vertical distances.



The distance of these points from the centre line is shown in the plan, being

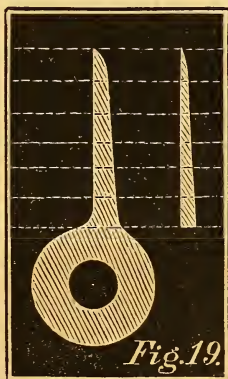
the distance from the centre of the hub to where each of the points appears in the plan.

For the points F and G, in the development, the same course is pursued. Find the versed sines of these points, then transfer them to the development, and take their distances from the centre line, as given in the plan.

Having found all the points, connect them and thus complete the development.

In Fig. 19, we have a section of the blade at the centre, showing the thickness, also a section taken near the edge of the blade. Now at any desired points of the development, draw lines perpendicular to the centre line; lay off the centre and side thickness at these points, and connect them by curves, as indicated. The drawing of the propeller is then complete.

The next case that we shall consider, is a propeller whose pitch expands from forward to after part of blade.

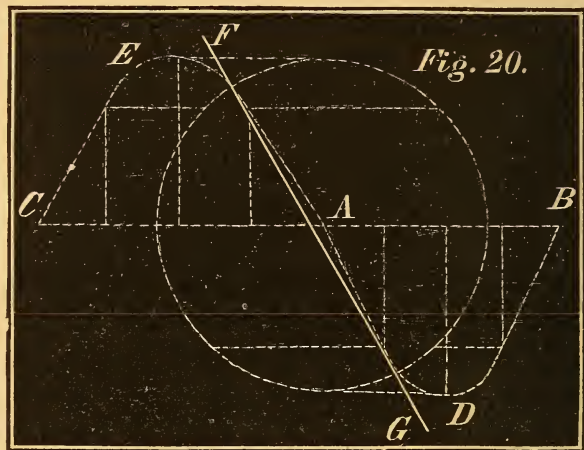


In making the drawing of this propeller, we first draw the side elevation of the hub, and then show the side elevation of the blades.

The previous method of drawing the helices to construct the plan will not answer.

Suppose we wish to lay down a propeller whose diameter is 14 feet, and whose pitch expands from

20 to 24 feet. In Fig. 20, make A B equal to 10 feet, half the pitch at forward part of blade, and A C equal to 12 feet, half the pitch at after part of blade. Then from A, as a centre describe a circle,



with a radius of 7 feet. Next construct the helices B D A and A E C, described by the extreme point of the generatrix, supposing it to have a pitch of 20 feet, for the first half of its revolution, and a pitch of 24 feet for the other half.

But the pitch of the screw does not expand in this manner, but gradually commencing with a pitch of 20 feet, and ending with a pitch of 24 feet. Hence, a curved line G A F drawn tangent to the two helices B D A and C E A, will represent the helix at the periphery.

This operation must be repeated, with a circle whose diameter equals that of the hub, to find the

helix at the hub, and also, with circles drawn at regular intervals between the hub and periphery, to find the intermediate helices.

When these are laid down, we can project the plan from the side elevation, as before shown, and the remaining operations are similar to those explained in the case of the true screw.

Now let us assume the screw that we desire to lay down, to have a pitch expanding from hub to periphery. We will suppose its diameter to be 14 feet, the diameter of the hub 2 feet, the pitch at the hub 15 feet, and at the periphery 21 feet.

Now it is evident that the pitch will vary at every point in the circumference. But we suppose it to expand regularly, and hence, we have an increase of 6 feet in pitch, for an increase of 6 feet in radius. That is, the pitch is increased 1 foot for every foot from the hub. So, by the method previously given, we can construct the helices of the periphery, hub and intermediate points, with their respective pitches. These helices are used to find the plan of the blade, the side and end elevations, and the development, being laid down as in the first case.

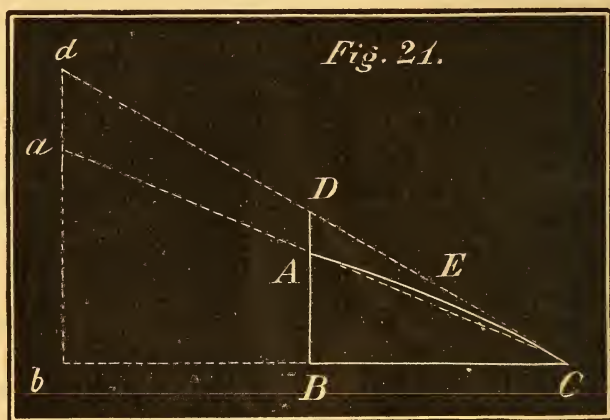
Now that we have finished the drawing of the propeller, it only remains to show the parts needed for the pattern-maker and moulder.

For the true screw, the only figures absolutely necessary, are the angle BAC , Fig. 15, the development and the thickness strips. The other views are

useful, however, so that the mould may conform to the shape of the designed blade in minute particulars.

In sweeping up a propeller, the angle is usually set several inches outside of the circumference of the wheel. This must be remembered in laying down the angle, which must be constructed for the distance from the centre of the hub, at which the angle is set. This distance should also be noted on the drawing, so that the moulder may know exactly where to place the angle.

For the propeller with pitch expanding from forward to after part of blade, we must have an angle $C A B$, Fig. 21, where $C E A$ is a curved line drawn tangent to the two paths of the generatrix.



The manner of constructing this curve is as follows: Let $b C$, represent the development of the circumference where the angle is set $b a$ and $b d$, the two pitches. The generatrix, however, does not

describe a whole circumference, but only the portion B C, so that B A and B D are the fractions of the two pitches. That is, the developed path of the generatrix at its commencement is C D, and at its termination C A. Hence, C E A drawn tangent to the terminal paths of the generatrix, is the path required, and C A B is the angle of the screw.

In sweeping up a blade, the after part must always be down. This should be remembered in constructing the angle.

For a propeller with pitch expanding from hub to periphery, two angles must be used as guide for the sweep; one, the angle at the periphery, and the other, the angle at the hub.

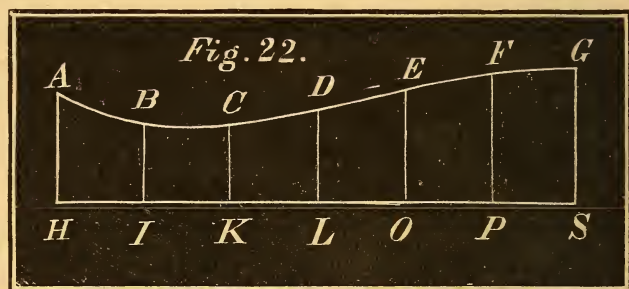
For cast-iron propellers, a good proportion of metal is $\frac{1}{3}$ by weight, Scotch pig, and the remainder scrap and American pig-iron.

For a composition propeller, a good mixture is as follows:

88 Copper	}	by weight.
10 Zinc		
2 Tin		

There are many rules for finding the area of propeller blades, but they are, as a general thing, only applicable in the case of a true screw, where no surface is cut away from the hub, or added at the periphery. The designs of blades are so varied, that these rules do not give very accurate results. A close approximation to the area of a blade, of whatever form, may be obtained from the development.

Suppose (Fig. 22) we desire to find the area contained between the curve A B C D E F G, the line H S, and the perpendiculars H A and S G. Divide the line H S into any even number of equal parts,



and erect perpendiculars I B, K C, etc., at every point of division. Measure each of these perpendiculars, and number them, commencing at the left hand. Thus H A designate No. 1, I B No. 2, K C No. 3, and so on. Then the area required is found by taking the sum of the extreme perpendiculars H A and S G, adding to this four times each of the even numbered perpendiculars, as I B, L D, and F P, also twice each of the odd numbered perpendiculars, as K C and O E; and multiplying this whole sum by $\frac{1}{3}$ of the distance between two perpendiculars, as H I.

EXAMPLE.—In the figure under consideration, let us divide the distance H S into six equal parts, each of which is one foot in length, and erect perpendiculars at the points of division. Let us also have the lengths of the perpendiculars given as follows:

H A = No. 1 = 4 feet. I B = No. 2 = 3.5 feet.

K C = No. 3 = 3.3 feet. LD = No. 4 = 3.7 feet.

E O = No. 5 = 4.3 feet. P F = No. 6 = 5 feet.

S G = No. 7 = 6 feet.

Then, by the rule, the area H A B C D E F G S is
 $(\frac{1}{3} \text{ of H I}) \times (H A + S G + 4 \times I B + 2 \times K C + 4 \times L D + 2 \times E O + 4 \times P F) =$

$(\frac{1}{3} \text{ of 1}) \times (4 + 6 + 4 \times 3.5 + 2 \times 3.3 + 4 \times 3.7 + 2 \times 4.3 + 4 \times 5) = 24.66 \text{ square feet.}$

This rule can be applied to the development of a blade of a propeller, as Fig. 18.

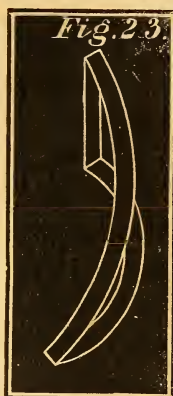
The centre line must be divided into an even number of equal parts, and then the area between this centre line and each half of the development can be calculated, as shown above. The sum of the two areas is the helicoidal surface of one blade. Multiply this by the number of blades, and we have the whole helicoidal surface of the propeller.

To find the acting surface of the propeller, we have only to compute the area of the end elevation of a blade (Fig. 17), and multiply it by the number of blades.

Propellers were formerly cast in flask moulds from patterns. But of late years this method has been seldom employed, and loam moulding has been usually practised. The process of sweeping up and moulding a propeller in loam is so interesting, that this article would be incomplete without some mention of it. We will, therefore, attempt a brief description of the mode of operation.

The pattern-maker first constructs an angle (Fig.

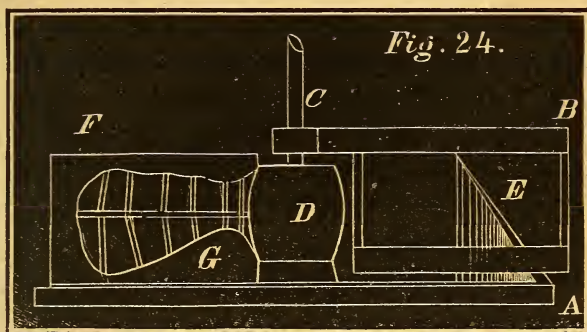
23), as a guide for the sweep. This angle is, of course, *the angle of the screw undeveloped*, and there-



fore its base is circular. It is constructed from the developed angle in the drawing sent to the shop, by transferring the perpendicular distance between the base and hypotenuse at various points. In casting large screws, the hypotenuse of the angle is usually faced with a strip of iron, to prevent wear. In Fig. 19 we have given the thickness of the blade on a line passing through the centre of the hub, perpendicular to the axis; and in Fig. 18 we have the thickness of the blade, taken at various points of this line, on lines perpendicular to it. Thickness strips are made, corresponding to these sections, the strips perpendicular to the centre strip, being made in two pieces, divided at the centre line. These strips are generally of inch or inch and a quarter stuff. The sweep and the hub complete the articles provided by the pattern-maker; and when the hub is very large, this is also swept up.

The moulder provides a plate, A, Fig. 24, of from 10 to 20 inches greater diameter than that of the propeller. A rod C is secured at right angles to the plane of this plate, and serves as a spindle for the sweep. A level bed is first swept up upon the plate, with a slight depression at the periphery, just the width of the base of the angle, and a cylindrical

elevation in the centre, upon which the hub is placed. When this bed is perfectly dry, the hub *D* is put in its place, and the sweep *B* is secured to the spindle. The angle *E* is also placed at the periphery of the



bed. Now, it is evident that if the sweep revolves around the spindle, advancing at the same time in an axial direction (as it must do, from the fact of its contact with the face of the angle), its lower edge will be the generatrix of a screw. So a bed of loam and brick is built upon the plate, and by the aid of the sweep, its face is made to coincide with the flat face of one blade of the propeller. This operation must be repeated, to sweep up the other blades. Let *F* represent the face of one of the beds that has been swept up. It is covered with a coat of parting sand, and then we are ready to mould the blade. The line passing through the centre of the hub, perpendicular to the axis, is drawn on this face by means of a spirit-level. The centre thickness strip is then put on the face along this line, and

secured lightly by nails, and the other strips are also secured in their proper places. When this is done, it is easy to mark the outline, G, of the blade. The moulder then fills in the spaces between the strips with sand, and with the aid of the strips readily gives it the shape of the blade. The strips are then removed, and the spaces previously occupied by them are filled with sand; so that we have a complete mould of the blade. It only remains to construct the cope. A layer of sand and loam is put over the face and mould of the blade, and the cope is built over the face of bricks and loam, strengthened at short intervals by iron plates and rods. An iron plate forms the top of the cope, and there are lugs on this and on the bottom plate, so that the mould and cope can be finally connected by bolts. When the cope is completed, it is lifted off, and the mould of the blade is removed from the face. We then have the shape of the blade accurately preserved in the cope. When all the blades have been similarly formed, the moulder removes the hub, and introduces the core. Where a hub has been swept up, and constructed of bricks and loam, it can be easily broken to pieces and removed. When it is made of wood, and cannot readily be drawn, it is removed, a piece at a time, or there are partings in the beds upon which the blades are moulded, so that these beds may be partially removed, and replaced when the hub is taken out. This completes the mould, at least so far as there is anything novel in its con-

struction. Of course, provision must be made for vent; the mould must be dried, and buried in a pit, before casting the propeller.

§ 6. *Combustion of Coal.*

Combustion is merely the combination of any substance with oxygen, by which union heat is developed. In the combustion of coal, carbon is the principal substance that unites with oxygen, and the air is the source from which the oxygen is derived. In 100 pounds of average anthracite coal the principal constituents are :

- 88 pounds, Carbon.
- 3 pounds, Hydrogen.
- 1 pound, Nitrogen.
- 1 pound, Oxygen.
- 7 pounds, solid refuse, or ashes.

On the application of heat to the coal, a gas is evolved consisting of two atoms of hydrogen and one of carbon. If air is now admitted to the gas, the hydrogen unites with an atom of oxygen and passes off as steam, while the carbon uniting with two atoms of oxygen forms carbonic acid. Thus we need four atoms of oxygen for the perfect combustion of this gas. Atmospheric air consists mainly of oxygen and nitrogen, an atom of oxygen to every two atoms of nitrogen, or, as the volume of an atom

of nitrogen is twice that of an atom of oxygen, we say that atmospheric air contains 20 per cent. of oxygen and 80 per cent. of nitrogen, with regard to volume. An atom of nitrogen weighs $1\frac{3}{4}$ times as much as an atom of oxygen; so that the constituents of air are in the proportion, by weight, of 1 pound of oxygen to $3\frac{1}{2}$ of nitrogen. So for every volume of oxygen that is required in a furnace, five volumes of air must be admitted.

After the combustion of the hydrogen in the coal is effected, that of the carbon commences, and this is, in fact, the main substance, which we desire to consume as perfectly as possible. In a furnace, carbon unites with oxygen in two proportions, forming carbonic acid and carbonic oxide. There is another compound of carbon and oxygen, but that is not formed in the combustion of coal.

Carbonic acid is a gas consisting of one atom of carbon and two of oxygen. As the relative weight of an atom of carbon, referred to hydrogen as a standard, is 6, and of oxygen 8, the weight of one atom of carbonic acid is 22. Its volume is the same as that of an atom of hydrogen, or 1.

Carbonic oxide is also a gas consisting of one atom of carbon and one of oxygen, having, therefore, an atomic weight of 14. Its volume, however, is the same as that of carbonic acid.

Oxygen unites directly with carbon to form carbonic acid, which is the result of perfect combustion.

But if carbonic oxide is one of the products of combustion, it is evident that heat is lost; for carbonic oxide is convertible into carbonic acid by the addition of another atom of oxygen, and heat is the result of the union. As carbonic acid is the result of the union of oxygen and carbon in the furnace, we must explain how it is that carbonic oxide can form one of the products of combustion. If air enters the ash pits and oxygen unites with the carbon, carbonic acid is formed; but this gas passing up through the coal, may unite with another atom of carbon and form carbonic oxide, so that the carbon will pass away half consumed. Now, if we can supply this carbonic oxide with another atom of oxygen, carbonic acid will again be formed, and the combustion is complete. For this reason air is sometimes admitted through the furnace doors above the fire.

While discussing the subject of combustion, we must speak of the plans of using water for fuel. Water, which was formerly supposed to be an element, is composed of hydrogen and oxygen, one atom of each, or by volume, two parts of hydrogen to one of oxygen, and by weight, one part of hydrogen to eight of oxygen. Now, as the combustion of hydrogen produces intense heat, it was thought that water could be decomposed and the hydrogen consumed to great advantage. Water can readily be decomposed by contact with carbon, at a high temperature; so it was proposed to admit water in the

form of superheated steam, to charcoal or coke, at a temperature of about 1800° . Then, the water being decomposed, the oxygen would unite with the carbon and form carbonic acid, while the hydrogen set free, if ignited in the air, would again become water and develop much heat in the process. This is a very plausible theory, except for the impossibility of creating force. Experiment and reason both confirm the fact, that the heat required to decompose the water is just as great as that produced by the subsequent combustion of its constituents. All schemes for producing additional heat by the use of water as fuel, may be classed among perpetual motions. Practically, we lose all the heat required to raise the water into steam, before it is admitted to the furnace.

The draft in a chimney or smoke-pipe is caused by the difference of pressure between the heated air within and the atmosphere without. Hence, the higher we make a chimney, the greater will be the draft. Also, cylindrical chimneys are the best, as there is less friction of the heated air and gases. Theoretically, the area of a chimney should be greater than the area for the admission of air to the furnaces, on account of the chimney expelling this air, and also the products of combustion. Let us determine the relation. In doing this, the table given below will be found serviceable.

Substance.	Atomic Weights.	Volumes.
Hydrogen	1	1.
Carbon	6	.5
Oxygen	8	.5
Nitrogen	14	1.
Watery Vapor	9	.14
Carbonic Acid	22	1.
Air	36	2.5
Carbonic Oxide	14	1.

As the atomic weight of hydrogen is 1, and of carbon 6, in anthracite coal we shall have 3 atoms of hydrogen for every $88 \div 6 = 14.66$ atoms of carbon. We will neglect the other constituents, as they would not affect the result materially. Now, to effect the perfect combustion of this carbon, we must have $14.66 \times 2 = 29.32$ atoms of oxygen, and for the hydrogen 3 atoms, or 32.32 atoms of oxygen in all. With this oxygen, $32.32 \times 2 = 64.64$ atoms of nitrogen must be admitted. The volume of this 64.64 atoms of nitrogen is 64.64, and of the 32.32 atoms of oxygen $32.32 \div 2 = 16.16$, so that the total volume of the air admitted to the furnace is $64.64 + 16.16 = 80.8$. Now let us look at the volumes of the products of combustion, and then we shall have the whole volume passed through the smoke-pipe. The volume of the carbonic acid formed from the 14.66 atoms of carbon, and the 29.32 atoms of oxygen, is 14.66. The nitrogen in the air that contains this oxygen is $29.32 \times 2 = 58.64$ atoms, and

its volume is 58.64. The volume of the three atoms of water, formed by the union of the three atoms of hydrogen with three atoms of oxygen, is $.14 \times 3 = .42$. The nitrogen passing through with this oxygen is $3 \times 2 = 6$ atoms, and its volume is 6. So we have, for the volumes passing through the smoke-pipe :

	14.66	volumes, carbonic acid.
	58.64	" nitrogen.
	.42	" watery vapor.
	6.	" nitrogen.
Total,	79.72	volumes.

By this, as the relation between the air admitted to the furnace, and the products of combustion, is as 80.8 to 79.72, it would seem that the areas should be about equal. But gases expand about $\frac{1}{491}$ of their volume for every degree of heat Fahrenheit that they receive. Let us suppose that the air entering the furnace has a temperature of 100° , and that the products of combustion have a temperature of 250° . Their volume will then be increased $150 \div 491 = .3055$. Hence the volume of the products of combustion is $79.72 + (79.72 \times .3055) = 103.05$, and the relation between the areas for admitting air and discharging the gases is as 80.8 to 103.05. But no furnaces are so well constructed as to absorb all the oxygen from the air passing through them. Indeed, it is estimated that about $\frac{1}{4}$ of the oxygen passes off

uncombined. So it may be well to allow 25 or 30 per cent. more space for the admission of air to a furnace than is barely required for perfect combustion. If the combustion is incomplete, we form carbonic oxide, which has the same volume as carbonic acid, but only develops half the heat.

§ 7. *Erection of Engines.*

As the contracts for the hull and machinery of steam vessels are at present issued to the shipbuilder and engineer simultaneously, the engineer is thereby granted a sufficient time to have the work prepared and temporarily erected before the ship is ready to receive it. The shipbuilder generally adjusts the dead wood for the propeller shaft, and sets it in a parallel line with the load line, and the centre fore and aft line of the ship.

With all marine engines, whether propeller or side-wheel, the constructing engineer takes the fore and aft (centre line) as the base of his work longitudinally, and the level of the deck beams as the base transversely or athwartship. From the deck (in propellers) the fore and aft (centre) line is transferred at the midship section to the centre of the stern-post. The point of contact with a perpendicular line from deck will, when parallel with the load line, give the main shaft line. This is the base from which all others are obtained, as all the motions of the engines are either parallel or perpendicular

thereto. Athwartship the work is levelled by the deck beams (lower side), and made parallel to them, as it is from the deck that the ship is levelled or trimmed.

It is customary for the constructing engineer to furnish plans of the height and size of the cross keelsons, etc., used for the foundation of the engines. When the hull has sufficiently advanced to allow the engineer to proceed with the erection of the engines on board, the form of the base of bedplate is transferred by means of a template. The centre line of shaft is marked thereon, also diagonal points, by which the centre line is governed from distortion, placed in proper position and marked off on board, using the main shaft line fore and aft, and a line parallel with the level of deck beams athwartships, to determine the plane of the base. The foundations are then pricked off at the proper heights (making due allowance for screwing down the foundation keelsons), and the bolt holes marked off, ready for the borers, by which means everything is prepared to receive the bedplates, etc. In placing a side-wheel engine on board a vessel (a beam engine, for instance), care should be taken to obtain the fore and aft centre line accurately, as it is the most important, and the one from which all others are derived.

It is obtained thus: get the mean centre from outside to outside of planking on deck, and draw it fore and aft on the centre of the deck. Then get the athwartship line at right angles with the fore and

aft line, and level with the deck beams. To set the engine keelsons, transfer the fore and aft centre line to the main keelson, at right angles with the athwartship or main shaft line, and draw the line out of winding (by sight) with the fore and aft line. Then adjust the engine keelsons equidistant and parallel thereto. Level off the keelsons, so that the face for condenser will be at right angles with the above perpendicular line. Set the channel way so that the centre of the condenser will coincide with the fore and aft centre line. Erect the gallows frame, and adjust it in conformity to a line drawn from the lower fore and aft centre line, at right angles with the main shaft line, and proceed throughout with parallels and perpendiculars.

The boiler foundation keelsons are laid at a line so as to make the lower face of the boilers, and the line of the tubes, parallel with the load line fore and aft, and the deck beams athwartship. Care should be taken, for the preservation of the boilers, that oak is not used in contact with the iron, as a strong acid is generated therefrom, which is a powerful and rapid oxidizer, and will soon destroy the iron. Yellow pine is far preferable for foundations.

As the bases of boilers are very irregular, it is impossible to lay the foundations accurately, therefore a putty is generally used (made of whiting and linseed oil) to fill up the irregularities. Boilers are generally secured by braces, firmly bolted to the hull, to prevent them from becoming displaced by any

motion or strain. In ocean steamers it is advisable (if practicable) to place the boilers at the centre of gravity (fore and aft), and to have the coal bunkers extending equal distances from the same, with the entrance in the centre, so that the engineer may alter the trim of the vessel at pleasure, and keep her on the best running line. Care should also be taken by the designers to proportion the weight on each side of the keelson, to keep the ship in trim (athwartship); also to have the coal bunkers on each side of equal capacity, and equidistant from the centre.

All holes bored through the sides of ships for deliveries, blow-pipes, and sea cocks, should be first lined with lead, and then bushed with copper, to prevent the destruction of the timber, also to prevent leaks. The dead wood for a propeller shaft should first be accurately bored out with a boring bar, and then lined with lead pipe, through which dies should be drawn to make it lie close to the wood, and prevent leakage. It should then be lined with copper pipe, through which dies should also be drawn, to render it perfect. Brass boxes with lignum vitæ bearings, for a shaft cased with composition, should then be fitted in in segments and bolted on, so that when worn out, they can be replaced without injury to the dead wood, lining, etc.

Rust joints, composed of sal ammoniac, iron borings, and water were formerly employed for all the permanent joints around engines, such as where the steam-chest joins the ports of a cylinder, and the like.

They are out of use now, however, and faced joints take their place.

§ 8. *Steam.*

Steam, according to Dr. Lardner, is air made from water. It may be defined as the gaseous condition of water, and is formed when water boils. It is an elastic fluid, and when not in contact with water, follows the same laws as other non-permanent gases. That is, it expands about $\frac{1}{491}$ of its volume for every degree of heat Fahrenheit that it receives, and the elastic force remains unaltered; but as long as the temperature is constant, the elastic force varies inversely as the volume.

Steam in contact with water contains moisture, and is termed saturated or common steam. When separated from the water, and heated to a higher temperature than is due to its pressure, it is termed surcharged or superheated steam. Now let us observe the process of the formation of steam. Let us take a vessel containing water at the temperature of 32° , and apply heat to it, say from the flame of a spirit lamp. We will observe the time occupied in raising the temperature of the water to 212° , supposing the heat applied to be constant. For the sake of illustration, let us take this time as one hour.

When the water assumes the temperature of 212° , if the vessel is uncovered, and the barometer stands at 29.9, it will get no hotter, but steam will commence to escape, and the water will boil. If now

the time be noted, from the moment the water assumed the temperature of 212° until all the water is evaporated, it will be found to be $5\frac{1}{2}$ hours.

If all the steam were preserved in a receiver, it would be found to have a temperature of 212° , a volume 1696 times greater than the water from which it was generated, and a pressure of 14.7 pounds to the square inch.

Now, as it requires 180° of heat to raise the temperature of the water from 32° to 212° , and $180 \times 5\frac{1}{2}$, or 990° , to convert that water into steam, which continued to have a temperature of 212° , we say that the 990° of heat are latent. This gives us $212^{\circ} + 990^{\circ}$, or 1202° , as the total heat of steam generated in an open vessel, when the barometer stands at 29.9, or the pressure of the atmosphere is 14.7 pounds to the square inch.

The preceding demonstration has given the results in round numbers. The precise latent heat of steam, whose sensible heat is 212° , as determined by Regnault, is $966^{\circ}.66$.

When the pressure under which steam is generated is increased, the sensible heat is also increased, and the total heat (or the sum of the latent and sensible heat) is also increased. The volume of the steam diminishes as the pressure increases.

Table I. gives the temperatures and volumes of steam at different pressures.

TABLE I.

Pounds per Square Inch.	Elastic Inches of Mercury.	Force in Atmo- sphere.	Temperature Fahrenheit Degrees.	Volume.	Total Heat.
1	2.04	.068	103.	20958	1145.35
5	10.20	.340	163.065	4769	1163.61
10	20.40	.680	193.165	2435	1172.77
15	30.60	1.020	212.8	1169	1178.84
20	40.80	1.360	228.5	1281	1183.55
25	51.	1.7	241.	1044	1187.38
30	61.2	2.04	251.6	883	1190.66
35	71.4	2.380	260.9	767	1193.45
40	81.6	2.72	269.1	679	1195.84
45	91.8	3.06	276.4	610	1198.22
50	102.	3.4	283.2	554	1200.21
60	122.4	4.080	295.6	470	1204.06
70	142.8	4.76	306.4	408	1207.32
80	163.22	5.440	315.8	362	1210.23
90	183.62	6.12	324.3	325	1212.83
100	204.	6.8	332.	295	1215.14
110	224.4	7.48	339.2	271	1217.31
120	246.8	8.16	345.8	251	1219.36
130	265.2	8.84	352.1	233	1221.31
140	285.6	9.52	357.9	218	1223.09
150	306.	10.2	363.4	205	1224.76

§ 9. *Expansion of Steam.*

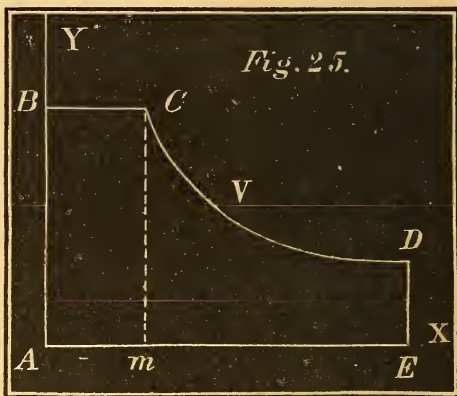
If we stop admitting steam to the cylinder before the piston has arrived at the end of its stroke, the steam already admitted will expand, and cause the piston to complete its stroke. Theoretically, this steam will expand according to Mariotte's law, or its pressure will be inversely proportional to the space

it occupies. Practically, there are many things to affect this law.

The question of expansion is now on its trial. So in this article we will only treat the subject theoretically.

The theoretical curve of expansion is an hyperbola of which $A X$ and $A Y$, Fig. 25, are the asymptotes, or lines which the curve cuts at an infinite distance.

Now the rectangle $A B C m$, represents the mechanical effect of the steam before expansion, and the area $C V D E m$, represents the mechanical effect during expansion. We call the area $A B C m$, unity, and we will find the area $C V D E m$, by means of Napierian Logarithms. These have the number 2.7182818, for a base, and the Napierian logarithm of any number may be found



from the common logarithm by multiplying the latter by 2.30258509. They are frequently called hyperbolic logarithms, because the numbers express the areas between the asymptotes and curve of the hyperbola, these areas being limited by ordinates parallel to the asymptotes. But such areas may be

made to denote any system of logarithms whatever. In the case of the hyperbolic logarithms, however, the asymptotes are at right angles to each other, and hence we see that the Naperian, or hyperbolic logarithm of the asymptote will give us the area required. Now the asymptote of the hyperbola in question is $n \times A \ m = n$, where n represents the number of times the line $A \ m$, which is unity, is contained in $A \ E$.

Hence, in order to find the mechanical effect of the steam during expansion, we have only to divide the space passed over by the piston before expansion, (which we call unity), by the number of such spaces in the whole length of the cylinder (which we call n), and take the Naperian logarithm of the reciprocal of this fraction. Adding the work performed before expansion, we have the total mechanical effect of the steam during one stroke.

But the mechanical effect is equal to the mean pressure, multiplied by the distance over which it is exerted. So we can obtain the mean pressure by multiplying the mechanical effect by the initial pressure of steam, and dividing by n , the distance through which the force of the steam is exerted.

The pressure at the end of the stroke will evidently be obtained by dividing the initial pressure by n .

The per cent. of gain by expansion will be obtained by multiplying the mechanical effect during expansion by 100.

EXAMPLE. — Suppose we have steam of 20 pounds pressure, and cut off at $\frac{1}{4}$ stroke.

Our fraction here is $\frac{1}{4}$, and $n = 4$.

Hyp. log. $4 = 1.386 =$ mechanical effect during expansion; and $1.386 + 1 = 2.386 =$ total mechanical effect.

$(2.386 \times 20) \div 4 = 11.93 =$ mean pressure.

$20 \div 4 = 5 =$ pressure at end of stroke.

$1.386 \times 100 = 138.6 =$ per cent. of gain by cutting off.

Table II. gives the hyperbolic logarithms that are needed for calculations at different points of cutting off.

TABLE II.

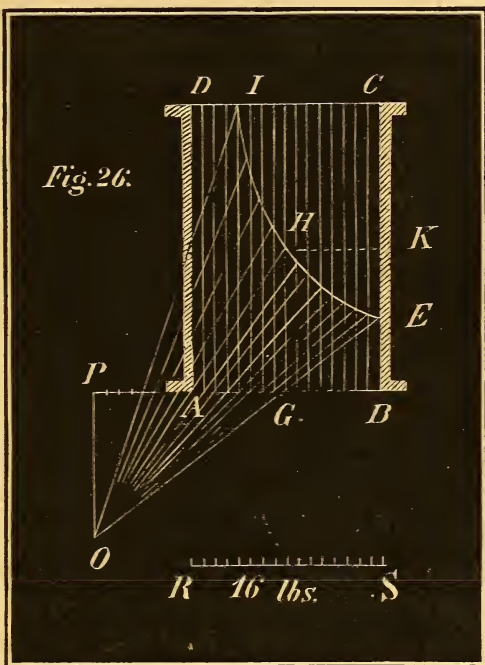
Number.	Hyp. Logarithms.	Point of Cutting.
1.143	.133	$\frac{1}{4}$ stroke.
1.333	.287	"
1.6	.47	"
2.	.693	"
2.666	.982	"
4.	1.386	"
8.	2.079	"

A very convenient way of laying off the theoretical curve of expansion, so as to find the pressure at any point of the stroke, is shown in Fig. 26.

Draw a section of a cylinder, A B C D, of the required diameter and stroke. Divide the diameter A B into any even number of equal parts, and through

the points of division draw lines perpendicular to $A B$. Produce the line $B A$, and make $A P$ equal to half of $B A$; also divide $A P$ into equal parts of the same size as those into which we divided $A B$. Then draw $P O$ perpendicular to $A B$.

Now suppose the steam is cut off at E , and expands through the remainder of the stroke. Draw a line from E through G , the middle point of $A B$, and note the



point O when it cuts the line $P O$. From O draw a line through the point of division on $A B$, next to the left of G , and note where it cuts the perpendicular drawn through the first point of division of the line $B A$. This is a point of the required curve. Then from O draw a line through the second point of division to the left of G , and note where it cuts the second perpendicular. This is also a point in the

curve of expansion. Continue this operation until all the points are found, and then describe through them the curve E H I.

Next lay off a line R S equal to the diameter of the cylinder, and divide it into as many equal parts as there are pounds in the initial pressure of the steam. This is our scale, and by applying it at any point of the stroke, the pressure of steam is indicated.

In the figure under consideration the number of divisions in A B corresponds with the number in R S, so that the pressure at any point of the stroke can be at once read off.

Before leaving the subject of expansion, we will take into consideration the gain in fuel derived by cutting off.

When we know the point of cutting off, and, consequently, what fraction of a cylinder full of steam is used, we can at once ascertain the per cent. of gain in fuel. We can also ascertain the mechanical effect of the steam. Now this mechanical effect will, of course, be less than it would be if the steam were not cut off.

We ascertain the difference between the mechanical effect at full stroke and the effect when the steam is cut off at a certain point, and then proceed to find the per cent. of fuel required to make the latter mechanical effect equal to the former. This we do by making a proportion, as follows :

The mechanical effect when the steam is cut off at a

certain point : the difference between the mechanical effects of steam following full stroke, and steam cut off at the given point of stroke :: the per cent. of fuel used when the steam is cut off at a given point : the per cent. of fuel required to make up the difference in mechanical effects.

This latter quantity must then be subtracted from the per cent. of fuel gained by cutting off at the given point, and the remainder is the per cent. of gain in fuel derived by cutting off, when the same effect is produced as if the steam followed full stroke.

EXAMPLES. — 1. What is the per cent. of gain in fuel, if the steam is cut off at half stroke, and made to produce the same effect as if it followed full stroke?

By Table II. the mechanical effect, if the steam were cut off at half stroke, would be 1.693, and as only half a cylinder full of steam would be used, the saving in fuel would be 50 per cent.; so that only 50 per cent. of fuel would be used. But if the steam followed full stroke, the mechanical effect would be 2.

$$2 - 1.693 = .307 = \text{difference in mechanical effects.}$$

Now to find the per cent. of fuel required to make up this difference, we make the proportion :

$$1.693 : .307 :: 50 : 9.$$

So that 9 per cent. more fuel must be expended to produce the same mechanical effect, cutting at half stroke, as if the steam followed full stroke. Hence,

$50 - 9 = 41$ per cent. gain in fuel, cutting off at half stroke.

2. What is the per cent. of gain in fuel, fulfilling the same conditions as in example 1st, except that the steam is cut off at quarter stroke?

$2.386 =$ mechanical effect, cutting off at quarter stroke.

75 per cent. $=$ gain in fuel, cutting off at quarter stroke.

$4 =$ mechanical effect, following full stroke.

$25 =$ per cent. of fuel used, cutting off at quarter stroke.

$4 - 2.386 = 1.614 =$ difference in mechanical effects.

$$2.386 : 1.614 :: 25 : 16.8.$$

$16.8 =$ per cent. of fuel required to make up the difference in mechanical effects.

$75 - 16.8 = 58.2 =$ per cent. of gain in fuel derived from cutting off at quarter stroke, the steam producing the same mechanical effect, as if it followed full stroke.

Now, it is evident that to make the mechanical effect of the steam, when it is cut off, equal to the effect when the steam follows full stroke, the initial pressure must be increased, so as to make the mean pressure the same in both cases.

Suppose that, when we follow full stroke, the mean pressure of the steam is a given number of pounds; it is required to find the initial pressure of the steam that is cut off at a certain point, which in expanding

will have the same mean pressure as in the first case. This is a problem which may be stated as follows :

Required to find a number, which, multiplied by the mechanical effect of the steam that is cut off, and divided by the distance over which this mechanical effect is exerted (this result being the mean pressure of the expanded steam), shall equal the mean pressure when the steam follows full stroke.

To find this number, we have only to make a proportion, thus :

The mechanical effect of the steam that is cut off : the number of times the steam is expanded, or the distance over which the mechanical effect is exerted :: the mean pressure following full stroke : the mean pressure required.

EXAMPLES.—In the two preceding examples, suppose the pressure of the steam when following full stroke to be 20 pounds : required to find the initial pressure of the steam that is cut off.

1st. When the steam is cut off at half stroke : Here, $1.693 = \text{mechanical effect.}$

$2 = \text{number of times the steam is expanded.}$
Hence, $1.693 : 2 :: 20 : 24.09.$

So that 24.09 is the initial pressure when the steam is cut off at half stroke, which will produce the same mechanical effect as steam of 20 pounds pressure following full stroke.

2nd. When the steam is cut off at quarter stroke : $2.386 = \text{mechanical effect.}$

$4 = \text{number of times the steam is expanded.}$

Then, $2.386 : 4 :: 20 : 33.5$.

So that 33.5 pounds is the required initial pressure of steam.

It must be remembered, that though the initial pressure of the steam is greater when cutting off, to produce the same mechanical effect as when following full stroke, the gain in fuel is effected from the fact, that in the first case, only half a cylinder full of steam is used, and in the second, only a quarter. Table III. gives the gain in fuel, derived by cutting off at various points; also the relation between the initial pressure of steam when cutting off and following full stroke.

TABLE III.

Point of Cutting Off.	Per Cent. of Gain in Fuel.	Initial Pressure Required.	
		Following Full Stroke.	Cutting Off.
$\frac{1}{2}$ stroke	11.73	1	1.008
$\frac{3}{4}$ "	22.4	1	1.03
$\frac{1}{2}$ "	32.	1	1.09
$\frac{1}{4}$ "	41.	1	1.18
$\frac{1}{8}$ "	49.6	1	1.32
$\frac{1}{16}$ "	58.2	1	1.67
$\frac{1}{32}$ "	67.6	1	2.6

When the pressure of steam following full stroke is given, the initial pressure of the steam that is cut off, can be found by multiplying the number in the last column, by the pressure of the steam that follows full stroke.

It must be remembered that all the results given

in the preceding article are theoretical. They must not be confounded with the gains in actual practice.

Back pressure is a constant prejudicial resistance, caused in the case of a condensing engine, by the impossibility of obtaining a perfect vacuum in the condenser; and in a high pressure engine, by the pressure of the atmosphere and resistance offered to the exhausting of the steam by friction and tortuous passages. This back pressure and the friction of the engine, interpose a limit even to theoretical expansion. For the effective pressure at the end of the stroke, which is the difference between the actual pressure at the end of the stroke, and the back pressure, must be at least equal to the pressure per square inch required to overcome friction. So, if we know the initial pressure of steam, the length of stroke and the required terminal pressure, we can find the point of cutting off by the relation between the volume and pressure of steam.

EXAMPLE.—Suppose the initial pressure of the steam is 20 pounds above a perfect vacuum; that the stroke is 4 feet; that the back pressure is 3 pounds per square inch, and the pressure necessary to overcome friction, 2 pounds per square inch. What is the shortest point of stroke at which the steam can be cut off?

$3 + 2 = 5$ pounds, a constant resistance. So that the least terminal pressure of the steam is 5 pounds.

Now as the initial pressure of the steam is 20

pounds, if it is expanded to 5 pounds, its volume must be

$$20 \div 5 = 4.$$

So that the steam is cut off at quarter stroke, or, as the stroke is 4 feet, at 1 foot from commencement.

The following example will serve as a good application of the principles enunciated in this article.

There are two engines, which we will designate as No. 1 and No. 2. No. 1 is a high-pressure engine, uses steam of 105 pounds pressure for gauge, and cuts off at quarter stroke. No. 2 is a condensing engine, uses steam of 20 pounds pressure, and cuts off at half stroke. The feed water is 100° in both cases. The back pressure in the condensing engine is 2 pounds per square inch, and the friction of the unloaded engine is 2.5 pounds per square inch in each engine.

Which will develop the greatest mechanical effect from one cubic foot of water evaporated, and how much coal will be required for No. 1 engine to evaporate the water, if 10 pounds are required for No. 2?

For No. 1 :

1.38 = mechanical effect during expansion.

$(1 + 1.38) \times 120 \div 4 = 71.4 = \text{mean pressure.}$

But as the steam exhausts into the atmosphere, and 2.5 pounds per square inch are required to overcome friction,

$71.4 - 15 - 2.5 = 53.9 = \text{mean effective pressure.}$

For No. 2 :

.69 = mechanical effect during expansion.

$$(1 + .69) \times 35 \div 2 = 29.575 = \text{mean pressure.}$$

Deducting the back pressure and friction,

$$29.575 - 2 - 2.5 = 25.075 = \text{mean effective pressure.}$$

Now let us suppose that the steam acts in both cases in a cylinder of one square inch cross section, and a stroke of one foot. As the volume of steam of 105 pounds pressure is 251 times as great as that of the water from which it is generated, one cubic foot, or 1728 cubic inches of water, will generate

$$1728 \times 251 = 433728 \text{ cubic inches of steam.}$$

The steam being cut off at quarter stroke, three cubic inches of steam are used at each stroke, and the number of strokes made by No. 1 engine will be

$$433728 \div 3 = 144576.$$

The distance in feet travelled by the piston, multiplied by the mean pressure, gives the mechanical effect.

The distance in feet is

$$144576 \times 1 = 144576.$$

Hence the mechanical effect is

$$144576 \times 53.9 = 7792646.4$$

For No. 2 the relative volume of the steam and water is 767, and one cubic foot of water generates

$$1728 \times 767 = 1325376 \text{ cubic inches of steam.}$$

As 6 inches of steam are used at each stroke,

$$1325376 \div 6 = 220896 = \text{number of strokes.}$$

Hence the mechanical effect is

$$220896 \times 25.075 = 5538967.2.$$

Calling the mechanical effect of No. 2 unity, that of No. 1 is

$$7792646.4 \div 5538967.2 = 1.406.$$

So that the per cent. of gain by No. 1 is

$$.406 \times 100 = 40.6.$$

Now let us find the coal required for No. 1. The total heat in the steam of No. 2 engine is $1193^{\circ}.45$, and since the temperature of the feed water is 100° ,

$1193^{\circ}.45 - 100^{\circ} = 1093^{\circ}.45 =$ heat imparted to a cubic foot of water by the consumption of 10 pounds of coal.

The total heat in the steam of No. 2 engine is $1219^{\circ}.36$, and

$1219^{\circ}.36 - 100^{\circ} = 1119^{\circ}.36 =$ heat required to be imparted to a cubic foot of water.

If 10 pounds of coal are needed in the first case, we shall now require

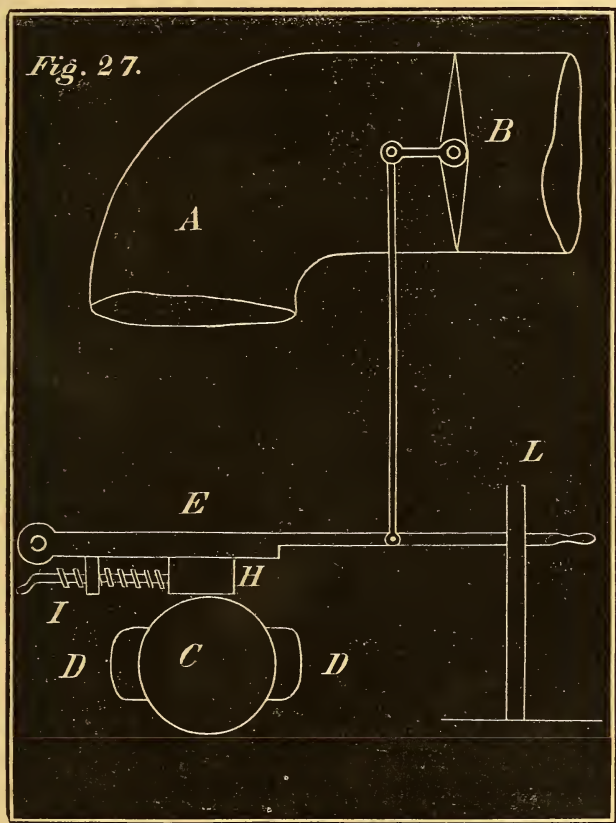
$$(1119^{\circ}.36 \times 10) \div 1093^{\circ}.45 = 10.237 \text{ pounds.}$$

§ 10. *Cut-Offs.*

As a necessary sequence to the subject of expansion, we have cut-offs, or arrangements by which the steam is shut off from the cylinder before the piston has completed its stroke. We will briefly notice a few of these.

The cut-off first in use on beam engines, when single puppet valves and one eccentric were employed, is represented in Fig. 27. There are two cams, D D,

on opposite sides of the main shaft C. As the shaft revolves, these cams strike the adjustable piece H,



and raise the cam board E, thereby opening the throttle valve B. When contact ceases between the cam and the piece H, the throttle valve closes and the steam is cut off. By moving the piece H to the right or left, we can make the time of contact, more

or less, at pleasure. The cam board must be raised and secured to the support L, to insure a supply of steam, when working the engine by hand.

The great objection to this cut-off, is the amount of clearance incident on its use; a large proportion of the steam in the side pipe, and in the steam pipe, in advance of the valve B, being expended at each stroke for which we get no return except from its expansion.

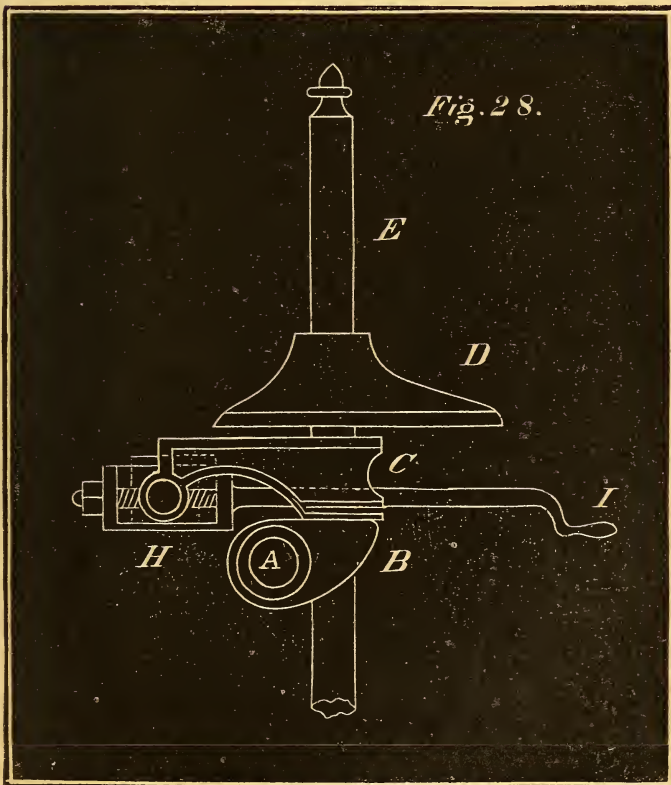
In 1846, Sickels's cut-off was introduced. In this arrangement the valve is detached from the lifting rod, at any desired point of the stroke, and falls to its seat. A dash pot is used to keep the valve from seating too hard. In the earlier forms of Sickels's cut-off, the valve had to be tripped by the time the piston arrived at the middle of its stroke, or not at all. As constructed at present, however, the valve may be closed at any desired portion of the stroke.

Stevens's cut-off next made its appearance. Though not readily adjustable, it has been very successful, and continues to give satisfaction. In this cut-off there are two eccentrics; one for the steam valves, and the other for the exhaust. The steam eccentric has great throw, and opens the valve by means of a toe and lifter. While there is contact between the toe and lifter, the valve is open, so that the point of cutting off is varied by making this contact of any required duration.

Cut-offs are so numerous, that it is impossible to notice all the varieties. Allen and Wells's arrange-

ment, and Winter's, complete the list of cut-offs that have been applied to any great extent to steamers fitted with puppet valves.

In Allen and Wells' cut-off, the lifting toe is raised by a cross arm on the rock shaft arm, but can be shifted from this at any point of the stroke and made to descend on an arm having motion coincident with the piston. This cut-off is readily adjustable.



A sketch of Winter's cut-off is given in Fig. 28. A, the rock shaft, is made to revolve by the eccentric. B is a cam on the rock shaft which revolves with the shaft and raises the adjustable toe C, which in turn raises the lifter D, and thereby opens the valve. When contact between B and C ceases, the valve is closed. So, by moving the adjustable toe C, to the right or left, we can cut off the steam at a given point of the stroke.

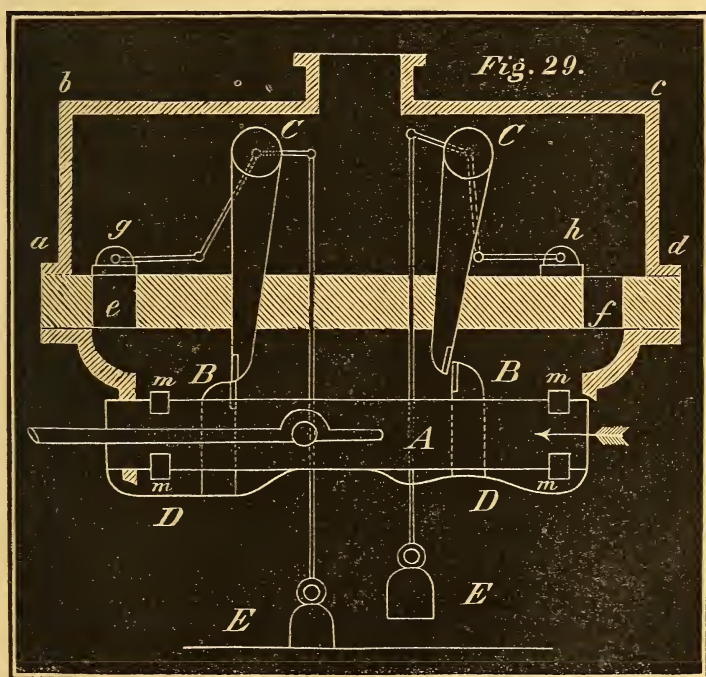
Let us now look at some of the means employed to cut off the steam when a slide valve is used. The first plan was to put on lap, or elongate the valve face on the steam side. But such a cut-off was not adjustable, and, moreover, had very restricted limits. A second valve chest was then put on above the chest in which the main valve worked, and a valve was introduced to regulate the admission of steam to the main steam chest. By this means, although the main steam valve might be open, if the supply of steam to the main steam chest was shut off, it would also be shut off from the cylinder.

This secondary valve, from the number of its ports, is called a gridiron valve. But this arrangement is not readily adjustable.

An English cut-off for slide valves, introduced into this country by Messrs. Merrick & Son, may be described as follows: There are two cut-off valves on the back of the main valve, which, covering the openings in the main valve at any desired point of the stroke, cut off the steam. These cut-off valves

are easily adjustable by means of a wheel, and right and left-handed screws on the stem.

In Green's cut-off, represented in Fig. 29, there are toes and lifters, acting directly on the steam valves. $a b c d$ is a section of the steam chest, e and f are the steam ports, g and h the steam valves. The steam ports are made long and narrow, so as to



give a large opening for a small throw. A , corresponding to the rock shaft, is a flat piece of metal receiving a rectilinear motion to and fro, from the eccentric. It has four guides, $m m m m$, to keep it

in position. B B are the lifting toes fitting into slots cut into the piece A. There are flat springs *m* under them, so that if forced down by pressure, they will return to their original positions when the pressure is removed. There are also lugs on the back of these toes which strike against an adjustable guard, whereby the height to which the toes rise, can be varied. The action of the cut-off is as follows: If A is moving in the direction indicated by the arrow, the toe B will strike against the lifter C, and open the valve *h*. When contact between B and C ceases, the weight E will close the valve. Meanwhile, the top of the other toe striking against the rounded side of the lifter, is pressed down without moving the valve until contact ceases, when the spring *m* forces it up to its former position. It will thus be seen, that to alter the point of cutting off, we have only to move the adjustable guard, thereby raising or lowering the toes and making contact between them and the lifters of more or less duration.

The link motion is sometimes represented as a cut-off; but to use a homely expression, it is not a pure cut-off, but a mixture of a cut-off and a squeeze-off. As the link is moved towards the centre, not only is the point at which the valve closes changed, so that the steam is cut off sooner, but the travel of the valve is also reduced, so that the steam is throttled.

§ 11. *The Indicator.*

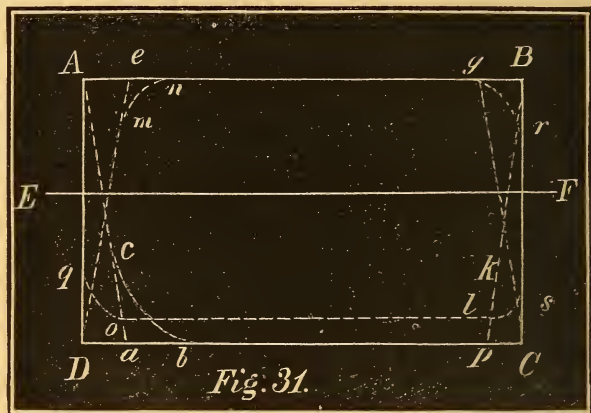
The steam-engine indicator consists essentially of a small steam cylinder, connected with the main cylinder by a pipe and stop-cock. There is a close fitting piston in this small cylinder, and above the piston is a spiral spring, which indicates by its scale the number of pounds pressure per square inch on the piston. There is also a parallel cylinder, covered with paper, which is made to revolve back and forth about $\frac{3}{4}$ of a revolution. A pencil attached to the piston of the steam cylinder traces a figure on this paper when the engine is in motion, showing the pressure on the piston at any point of the stroke. The cylinder on which the paper is placed must have motion coincident with that of the piston in the cylinder to which the indicator is attached. The figure made by the pencil is called an indicator, diagram or card. By an inspection of the diagrams from an engine, we can readily determine the mean pressure on the piston, the horse-power, the state of the vacuum, where the valves open and shut, etc., etc.

In the use of the indicator, as generally constructed in this country, much trouble is experienced in fast working engines by the piston jumping when steam is admitted to the cylinder, and making a waving line at the top of the diagram. Porter's indicator, represented in Fig. 30, obviates this in a great measure. A is the steam cylinder, and C the piston rod.

and attached to the proper part of the engine, whereby the cylinder E receives the required motion.

It will be observed that on account of the manner in which the pencil is attached, it will receive a considerable motion up or down for a very small motion of the indicator piston. This shows the reason of its smooth working, when applied to engines making a considerable number of revolutions per minute. As the indicator piston has only to rise and fall a very short distance, the spiral spring connected with it is stronger than those made for indicators of the usual construction. Now let us suppose the indicator to be attached to the engine from which we wish to take a diagram, the string which causes the motion of the paper cylinder being connected with a part of the engine having motion coincident with that of the piston. Some indicators are fitted with a small plug-cock in the steam cylinder, whereby all the water may be blown out of the pipe. But if this is not the case, the water must be blown out of the pipe by opening the stop-cock before the indicator is attached. When this is done, open the stop-cock and warm the steam cylinder of the indicator. Then close the stop-cock, and the piston will stand at the point marked O on the scale. If the pencil be put on the paper, the cylinder revolving, a horizontal line will be traced, and this we call the *atmospheric line*. The piston should then be forced down, until it stands at 15 pounds, and in that position, if the pencil be put on the paper, the *perfect vacuum line* will be

traced. Everything is then ready to take the diagram; to do which we have only to open the stop-cock, and put the pencil on the paper. If we suppose the valve to have neither lap nor lead, and the engine to be perfect in its action (which is, of course, only a theoretical case), the diagram will be the rectangle A B C D, Fig. 31. E F is the atmospheric line, traced by the pencil, when the stop-cock is



closed, and D C is the perfect vacuum line. Now, when the crank is on the centre steam is admitted, the piston rises a distance proportionate to the amount of pressure, and the pencil traces the line D A, called the *receiving line*. As the main piston makes a stroke, the paper cylinder revolves, and the pencil traces the horizontal line A B, the *steam line*, the indicator piston being kept up on a level with the point A by the pressure in the main cylinder. When the main piston arrives at the other end of the

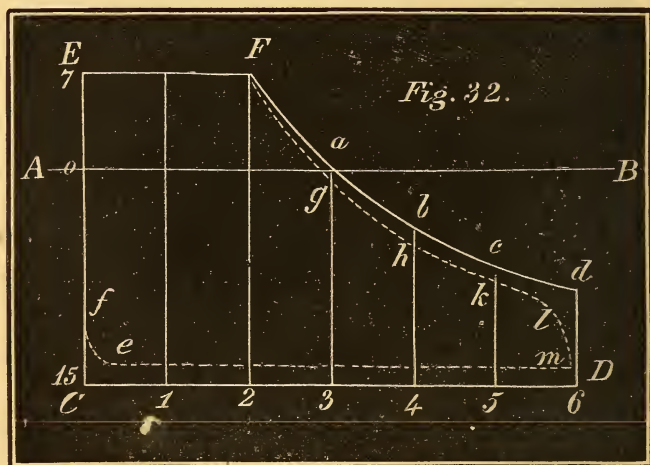
stroke, the exhaust valve is opened, and the pressure falls to the perfect vacuum line, causing the pencil to describe the line B C, the *exhaust line*. On the return stroke of the main piston, there will be a perfect vacuum in the cylinder, and the pencil will trace the line C D, the *vacuum line*. If the steam valve was set with lead, or so as to open before the end of the stroke, the steam line would have the direction *a A*. If the exhaust valve had lead, *g C* would represent the exhaust line, instead of B C. The exhaust valve is often made to close before the end of the stroke, so as to produce cushioning, and this would appear in our theoretical card as the hyperbola *b c*. If the steam valve opened too late, the receiving line would take the position D *e*.

(It will be understood that these are extreme cases, as represented in the diagram, and made so to aid in showing the principle clearly.) If the exhaust valve opened too late, the exhaust line would appear as B *p*. By accustoming himself to the meaning of the various directions taken by these several lines, an engineer can tell at once, on seeing a diagram, whether the engine from which it was taken is in good running order.

In the practical case of a diagram from an engine, the vacuum line would appear above the perfect vacuum line, as at *o s*, and the perpendicular distance between this line and the perfect vacuum line is the *back pressure*. The corner at A will be square if the valve is set rightly, and the ports are of sufficient

size. The corner at B has a slight rounding from where the exhaust valve opens at *g*. The corner *s* should be square, or nearly so. A *g r s o q* will then represent what is called a good diagram from a non-expansive engine.

In the case of an expansive engine, the theoretical curve of expansion will be an hyperbola. We have already shown one method of laying out the curve in the article on expansion, but we will indicate another, that will be found useful in connection with diagrams. In Fig. 32 A B is the atmospheric line, and C D is the perfect vacuum line; C E is the



receiving line, E F the steam line, and at F the steam is cut off, and the pencil describes the hyperbola F a b c d, called the *expansion line*. We can lay this out merely by applying Mariotte's law.

Divide the whole length of stroke CD into any number of equal parts, and observe how many of those parts the steam follows. In the case under consideration, the initial pressure of the steam is 22 pounds, and the steam follows two of the spaces into which we have divided the stroke. Then when the steam reaches the third space, its volume will be $1\frac{1}{2}$ times what it was originally, and its pressure will therefore be $\frac{2}{3}$ of 22, or $14\frac{2}{3}$ pounds. Similarly, as at the fourth division the volume is doubled, the pressure will be $\frac{1}{2}$ of 22, or 11 pounds. At the fifth division the volume is $2\frac{1}{2}$ times its original bulk, and the pressure is $\frac{2}{5}$ of 22, or $8\frac{4}{5}$ pounds, and so on. When all the points are found, describe the curve $F a b c d$. $E F a b c d D C$ is then the theoretical diagram, taken from an engine carrying 7 pounds of steam per gauge, and following $\frac{1}{3}$ of the stroke.

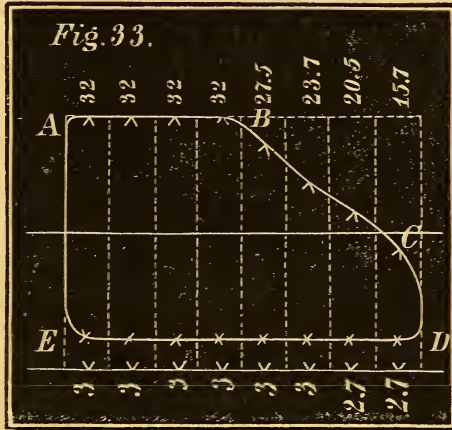
In the practical case the curve will usually fall a little below the theoretical curve. If it is very much below, it is caused by a leak, either in the exhaust valve or around the piston. If the actual curve is above the theoretical, it will be on account of a leak in the steam valve, whereby steam is admitted to the cylinder after the valve is closed. Our practical diagram is $E F g h k l m e f$. In drawing the theoretical curve on a diagram taken from an expansive engine, it must be remembered that all the steam in the clearance also expands. This clearance then must be reduced to an equivalent length of cylinder, and added to the end of the stroke.

In the case of a diagram taken from a high pressure engine, the whole card would appear above the atmospheric line, as the steam exhausts into the open air. The perpendicular distance between the lower line of the diagram and the atmospheric line would indicate the resistance to the motion of the piston, caused by vapor in the cylinder, obstacles to a free exhaust, and the like. The back pressure would be this pressure, plus the pressure of the atmosphere into which the steam exhausts.

The common way of finding the actual horse-power of an engine is by means of a diagram. That is, we get the most important thing, the mean pressure of the steam from the diagram. A horse-power, as agreed upon by all engineers, is the power required to raise 33,000 pounds one foot high in a minute. Hence, when we know the mean pressure per square inch on the piston, we can readily find the total pressure acting on its whole area. This being multiplied by the distance in feet that the piston travels per minute, will give the number of pounds raised one foot high in a minute by the piston. But as every 33,000 of these pounds represents one horse-power, we have only to divide by 33,000, and the operation is complete.

EXAMPLE.—Let A B C D E, Fig. 33, represent the diagram from which we propose to ascertain the mean pressure. Divide the atmospheric line, or the perfect vacuum line, into any number of equal parts, and erect perpendiculars at every point of division.

Then with a scale measure the effective pressure between each of these perpendiculars. (A scale can readily be constructed by observing that the perpendicular distance between the atmospheric and perfect vacuum lines is 15 pounds on the scale.) Thus,



between the first and second perpendiculars, the total pressure is 32 pounds, and the back pressure is 3 pounds, so that the effective pressure is 29 pounds. Measuring the pressure between all the perpendiculars, we have

$(29 + 29 + 29 + 29 + 24.5 + 20.7 + 17.8 + 13) \div 8 = 24$, as the mean effective pressure per square inch on the piston. (The mean effective pressure on the diagram taken from the other end of the cylinder, at a short interval from the time the diagram under consideration was made, should then be calculated. If the two results differ, take their mean as the pressure per square inch to be used in the calculation.) Now we will suppose the cylinder, from which this diagram was taken, to have a diameter of 60 inches and a stroke of 10 feet. We

will also suppose that the engine was making 20 revolutions per minute when the card was taken. (The speed of the engine, when a card is taken, should always be carefully noted for future reference.) Then the mean pressure acting on the piston is $2827.4 \times 24 = 67857.6$ pounds. As the engine is making 20 revolutions per minute, the distance passed over by the piston in that time is $10 \times 2 \times 20 = 400$ feet. Hence, the power exerted by the engine is equivalent to $67857.6 \times 400 = 27143040$ pounds raised one foot high in one minute, and the horse-power is

$$27143040 \div 33000 = 822.5.$$

To find the useful horse-power of the engine, we must remove the load and take a diagram, for the purpose of finding the mean pressure per square inch exerted in overcoming friction. We can then subtract this from the mean pressure acting on the piston when the load is on the engine, and that will give the mean pressure per square inch producing useful effect, or we can find the horse-power required to overcome friction, and subtract it from the total horse-power developed by the engine.

EXAMPLE. — Suppose that the diagram we have been considering in the previous example, was taken from a stationary engine when performing its average work. Then let us suppose the load to be taken off, so that the engine has only the friction of its parts to overcome. When it is making 20 revolutions per

minute, under these conditions, if we apply the indicator, we shall take a friction diagram. The mean pressure per square inch acting on the piston can then be calculated from this diagram, precisely as in the previous case. Let us suppose this pressure to be 2.5 pounds per square inch, it is then required to find the horse-power, producing useful effect, developed by the engine.

1st Solution. The mean pressure per square inch producing useful effect is $24 - 2.5 = 21.5$ pounds. Hence the useful horse power is

$$(2827.4 \times 21.5 \times 400) \div 33000 = 736.8.$$

2d Solution. As the mean pressure per square inch required to overcome friction is 2.5 pounds, the horse-power absorbed by friction is

$$(2827.4 \times 2.5 \times 400) \div 33000 = 85.7.$$

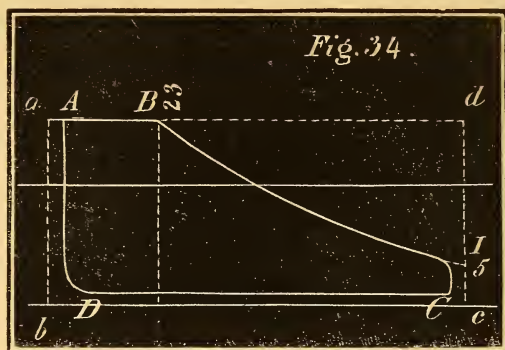
Hence the horse-power producing useful effect is

$$822.5 - 85.7 = 736.8.$$

The horse-power of a boiler can also be calculated by the aid of an indicator diagram. In the case of a boiler, every cubic foot of water evaporated per hour is considered equivalent to a horse-power. From a diagram we can ascertain how many cubic feet of steam are used in an hour, and, consequently, how much water has been evaporated. But the more usual calculation in regard to the efficiency of a boiler, is the number of pounds of water evaporated per pound of coal. Let us take an example.

A B C D, Fig. 34, represents a card taken from a

direct-acting propeller engine. We have given the following data: diameter of cylinder, 63 inches; length of stroke, 3 feet; revolutions per minute, 60;



clearance at each end of cylinder, reduced to equivalent length of cylinder, 1 inch; pounds of coal consumed per hour, 1500;

loss by blowing off, 15 per cent. It is required to find the number of pounds of water evaporated by the consumption of one pound of coal. At B, as indicated by the card, the steam is cut off, and expands through the remainder of the stroke. B is at one-quarter of the stroke, so we see that we use one-quarter of a cylinder full of steam of 23 pounds pressure, plus the clearance, at each stroke. Or, we can find the terminal pressure, as indicated by the diagram, by continuing the expansion line, as its path evidently would be but for the exhaust lead, to where it cuts the perpendicular $c d$, drawn one inch from the end of the stroke to include the clearance. This terminal pressure $C I$ being 5 pounds above a perfect vacuum, shows that there is a cylinder full of steam, plus the clearance, of 5 pounds pressure, used at each stroke.

By taking the fraction of the cylinder filled with steam, as in the first case, we lose all the steam that leaks into the cylinder, if the valves are not tight. In the second case we lose all the steam that condenses in the cylinder, and leaks past the piston or through the stuffing-box. Still the last method is the most correct, and is generally employed. It is evident that in neither case can we obtain all the steam that is generated, since that lost by leakage cannot be calculated.

We will use the terminal pressure in solving this example. The method, however, is the same in either case.

The quantity of steam used at each stroke will be the capacity of the cylinder plus the clearance, or,

$$21.647 \times 4.0833 = 87.39 \text{ cubic feet.}$$

In an hour the engine makes :

$$60 \times 2 \times 60 = 7200 \text{ strokes.}$$

Therefore, $87.39 \times 7200 = 629208$ cubic feet of steam used in an hour. But the relative volume of steam at 5 pounds pressure, and water, is 4769. So that

$629208 \div 4769 = 131.93$ cubic feet of water evaporated per hour. As a cubic foot of sea water weighs 64.3 pounds,

$131.93 \times 64.3 = 8483.1$ pounds of water evaporated per hour. Now, the 1500 pounds of coal consumed in an hour, both evaporates this water and heats the water blown off. And since 15 per cent.

of heat is lost by blowing off, $1500 - (1500 \times .15) = 1275$ pounds of coal, evaporate 8483.1 pounds of water. Therefore,

$8483.1 \div 1275 = 6.66$ pounds of water, evaporated by one pound of coal.

Another way of introducing the loss by blowing off, is as follows: Since 1500 pounds of coal evaporates 8483.1 pounds of water, 1 pound of coal will evaporate

$$8483.1 \div 1500 = 5.66 \text{ pounds of water.}$$

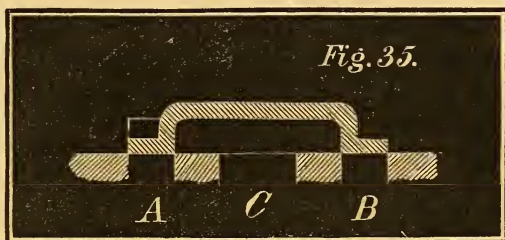
But, as 15 per cent. of heat is lost, the 5.66 pounds of water only represents 85 per cent. of the real efficacy of the coal, and the water evaporated by one pound of coal will be

$$5.66 \times 100 \div 85 = 6.66 \text{ pounds.}$$

§ 12. *The Slide Valve.*

A three-ported slide valve in its simplest form is represented in Fig. 35. The valve has the position shown in the sketch, when the piston is at one end of the stroke. When the piston commences to move, the valve also receives motion from the eccentric. If it moves to the right, the port A will be uncovered and steam will be admitted into one end of the cylinder, while the port B will be open to the exhaust port C, and the steam in the other end of the cylinder will be exhausting. When the valve has moved far enough to uncover the port A, (at which time the

piston will have made half a stroke), it commences to move to the left, and at the termination of the stroke, the port A will again be closed. On the return stroke of the piston, the



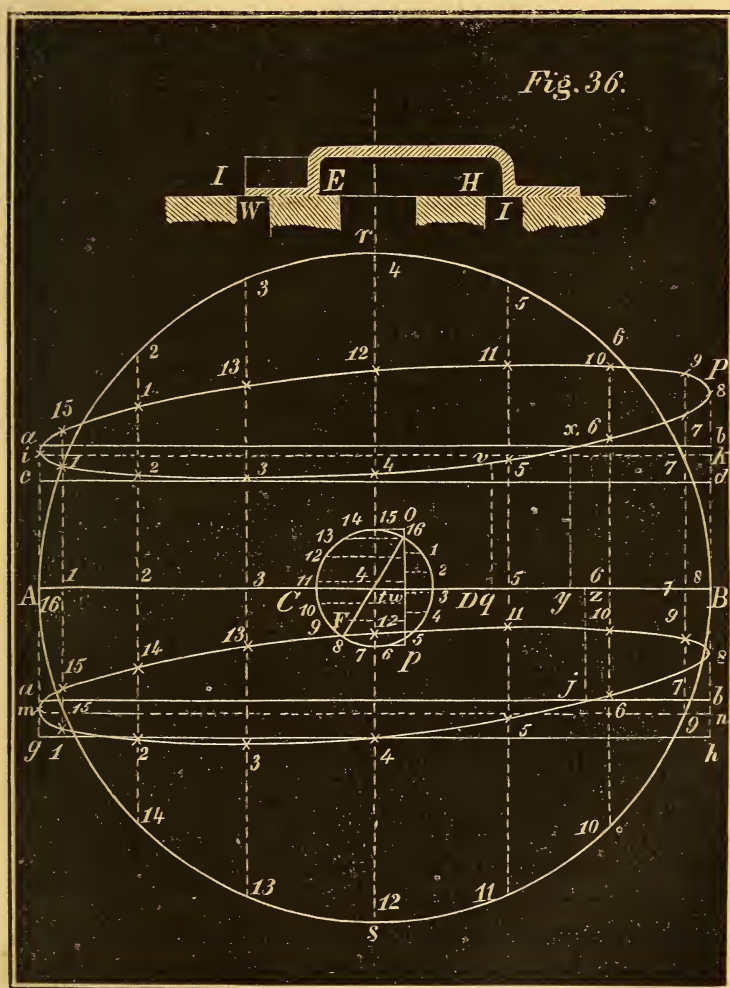
valve will continue to move to the left until the port B is fully open, when it will again move to the right, closing the port B at the termination of the stroke. It is evident that the motions of the valve and piston are at right angles; for the valve is at half stroke when the piston has completed its stroke, and vice versa. So to set the eccentric of this valve, we have only to make the line joining the centre of the eccentric and the centre of the shaft, perpendicular to the line joining the centre of the crank-pin and the centre of the shaft. The throw of the eccentric, or the travel of the valve, (supposing the eccentric rod to be directly connected to the valve stem), is evidently equal to twice the breadth of the steam port, and the face of the valve is just as wide as the steam port.

With the valve set in this manner, the steam is not admitted to the cylinder until the crank is on the centre. But it is found desirable to admit steam a little before the end of the stroke; and this can readily be accomplished by turning the eccentric on

the shaft. This we call giving the valve *lead*. Thus, if the steam port is open a sixteenth of an inch, when the crank is on the centre, we say that the valve has a sixteenth of an inch lead. But if we open the steam port A before the end of the stroke, we also open the port B to the exhaust, and the amount of this opening at the termination of the stroke, we term the *exhaust lead*.

Now, if we wish the port to be closed before the termination of the stroke, we make the face of the valve longer, or put on *lap*. In this case the throw of the valve must be increased by an amount equal to twice the lap. But if excessive lap be put on, it is evident that the travel will be so much increased as to permit the steam to exhaust at an early part of the stroke. To obviate this, we must put lap on the exhaust side of the valve. This has a bad effect in causing the exhaust valve to close too soon. This will be seen clearly in the illustration of the geometrical action of the slide valve, Fig. 36. Let AB equal the length of stroke of our engine drawn to any scale. We will give the valve an amount of lap on the steam side equal to half the breadth of the steam port. The travel of the valve will then be equal to three times the breadth of the steam port. On A B, as a diameter, describe a circle which will represent the path described by the centre of the crank-pin, while the piston is travelling twice the distance A B. Divide this circle into any number of equal parts, and draw perpendiculars to A B from

every point of division. We shall thus determine the position of the piston corresponding to that of



the crank at various points. With the same centre

t , as that of the circle $A r B s$, describe a circle $C o D p$, having the travel of the valve for its diameter. This will represent the path of the centre of the eccentric, during a revolution of the crank. When the crank is on the centre, the line connecting the centre of the crank-pin and the centre of the shaft will be $A t$; so that if the valve had neither lap nor lead, the line connecting the centre of the eccentric and the centre of the shaft should take the direction $t r$, perpendicular to $A t$. But in the present case, when we have both lap and lead, we make $t u$ equal to the sum of the lap and lead, and through u , draw a line parallel to $t r$. Connect the point o where this line cuts the circle with the centre, and $o t$ will be the proper position for the line connecting the centre of the eccentric and the centre of the shaft, when the crank is on one centre. When the crank is on the other centre, this line will appear at $t F$. Divide the circle $C o D p$ into the same number of equal parts as we divided the circle $A r B s$, and draw perpendiculars to $o p$ from every point of division. The lengths of these perpendiculars show the distances travelled by the valve at various points. Now, let $A B$ represent the centre of the exhaust port. Then draw $a b$ and $c d$ to represent the width of one steam port, and $e f$ and $g h$ for the other. Make $a i$ equal to $l w$, the steam lead, and draw a line $i k$ parallel to $a b$. This is the line to which all our measurements must be referred since the valve commences to move from this position. Thus, when

the crank has moved the distance $A\ 1$, the centre of the eccentric has moved the distance $o\ 1$, and the perpendicular distance of this point 1 from $o\ p$ will be the distance the valve has travelled. Lay off this distance below the line $i\ k$ on the first perpendicular, and the point so determined will represent one position of the valve. Similarly, when the crank has travelled the distance $A\ 2$, the centre of the eccentric has passed over $o\ 2$, and the valve has travelled the perpendicular distance between 2 and $o\ p$. Lay off this distance on the second perpendicular below $i\ k$, and we determine the position of the valve at another point of the stroke. Find the position of the valve in this manner at every point of division, and through the points so found draw a curve which will represent all the positions of the valve during one revolution of the crank. It must be observed, in laying off perpendicular distances from $o\ p$, that all points to the right of $o\ p$ are positive, and are laid off below $i\ k$, while all points to the left of $o\ p$ are negative, and must be laid off above $i\ k$. We have not yet determined the amount of exhaust lap, but this can readily be fixed, now that the motion of the valve is represented. When the piston has made one stroke, the crank is at B and the valve is at P. Now, if the face of the valve was only $1\frac{1}{2}$ times the width of the port, the whole port would be open for the steam to exhaust. So we must put lap on the exhaust side of the valve, and we put on enough to have the exhaust lead equal to

II I. This gives us the width, w E, of the valve face.

From the curve A i P, we can readily find the position of the valve, corresponding to any position of the piston. Thus, when the piston has travelled the distance A q , the valve is at v , and the distance the port is open is equal to the perpendicular distance between v and the top of the port a b . At x , where the curve cuts a b , the port is closed, and the steam expands during the remainder of the stroke from y to B.

We can readily lay down the curve described by the lower extremity of the valve. The distance e m between e f , the top of the port, and m n , is the exhaust lead, and we have only to transfer the distances of the various points in the first curve from i k to their respective distances from m n , on the same perpendicular on which they were first laid down. By this curve we see that the exhaust opening is closed at j , when the piston has travelled the distance A z . The steam being pent up in the cylinder, from z to B, occasions excessive cushioning, and that is the reason why expansion by means of lap on a slide valve cannot be carried to any great extent. About two-thirds of the stroke is the earliest point at which a slide valve should close the steam port.

In setting slide valves, it is a common practice with engineers to set the eccentric so that the valve shall have from $\frac{1}{16}$ to $\frac{1}{4}$ of an inch steam lead, accord-

ing to the size of the engine and number of revolutions. This is generally considered a great abundance, to make the engine work smoothly and efficiently. Therefore, when the engine is in motion, if there should be any thumping, the first thought of the engineer is, that the connecting rod or pillow block brasses are slack, and require setting up. As he set the valve himself, saw that it had $\frac{1}{8}$ or $\frac{1}{4}$ inch steam lead, as the case may be, he is sure that there is no trouble in that quarter. So the brasses are keyed up, and as a natural consequence get hot, and the engineer will ruin the journals by continually running cold water on them.

If the engine has the link motion, as soon as a thump is heard the engineer usually runs up the link until the engine works smoothly. By this action the travel of the valve is diminished, so that the steam is throttled or wire drawn, and there is an excessive cushioning of the exhaust steam, so that the engine is not developing all the power that it should.

An indicator diagram is frequently taken when an engine thumps, and in nine cases out of ten it shows a want of steam lead. But as the engineer saw the lead when the valve was set, of course the indicator is wrong, and he goes on in his vain endeavors to stop by keying up a thump caused by want of steam lead. The authors of this work, while on duty at the Norfolk Navy Yard, have set more than a hundred slide valves (at the suggestion of Fleet

Engineer Theodore Zeller, U. S. N.) on the following plan: One-eighth of an inch is allowed for the lost motion of the shaft, and $\frac{1}{16}$ of an inch for every connection between the eccentric and the valve. Thus, if there were six connections, we allow $\frac{1}{16}$ for each, making $\frac{3}{8}$ and $\frac{1}{8}$ for the shaft, making $\frac{1}{2}$ inch, to which we add $\frac{1}{16}$ for actual lead. So in setting the valve we give it $\frac{9}{16}$ of an inch apparent lead, but when the engine is in motion, $\frac{1}{2}$ inch of this lead is annihilated by lost motion, and the valve will only have $\frac{1}{16}$ of an inch lead, as contemplated.

When the slide valve of an engine is set in this manner, the engine will work smoothly, and will show no hesitation in passing the centres; there will be no thumping or jarring, and the plague of hot journals will be unknown, as a general thing. Experience confirms the truth of this statement, and the indicator shows that the theory is a correct one. Engineers are too apt to consider that the indicator is out of order when a diagram does not suit them, but they should recollect that an indicator must be very much deranged when it will not show the lead of a valve correctly.

The foregoing method of setting slide valves is earnestly recommended to the attention of all engineers. Even if they do not believe in it, let them test it. Anything promising such important results is certainly worth a trial, and we are sure that they will not regret having made the experiment.

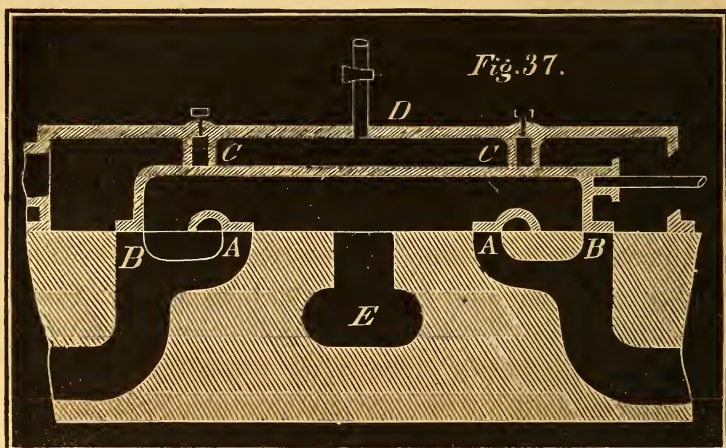
§ 13. *Balanced Valves.*

In the use of single puppet valves much difficulty was experienced in working an engine by hand, unless a very long starting bar, or an arrangement of levers, was employed. But the great objection is the power required to work these valves while the engine is in motion. This led to the adoption of the double puppet valve, consisting of two single valves connected to one stem. Theoretically the upper and lower parts of this valve should be of the same diameter. But the upper half of the steam valve is made a little larger, since if we neglect the weight of the valve, lifting rod, etc., and suppose both halves of the valve to be equal, then there will be an equilibrium, and the valve will remain in any position in which it may be placed. But in the case of the exhaust valve, the lower half is made the largest, so as to give security against the valve being forced from its seat by the pressure of steam.

The Cornish valve is balanced, and partakes of the nature of a double puppet valve. The seat of the valve is similar to a double puppet valve turned upside down, and the valve answers to the reversed seat of the double puppet valve.

The arrangements for relieving the pressure on the back of slide valves are numerous and varied. Prominent among these is the ring on the back of the valve. This is illustrated in the sketch of the

double ported valve, Fig. 37. On the back of the valve is a ring C C secured to the steam chest, against which the valve works steam tight. D is a

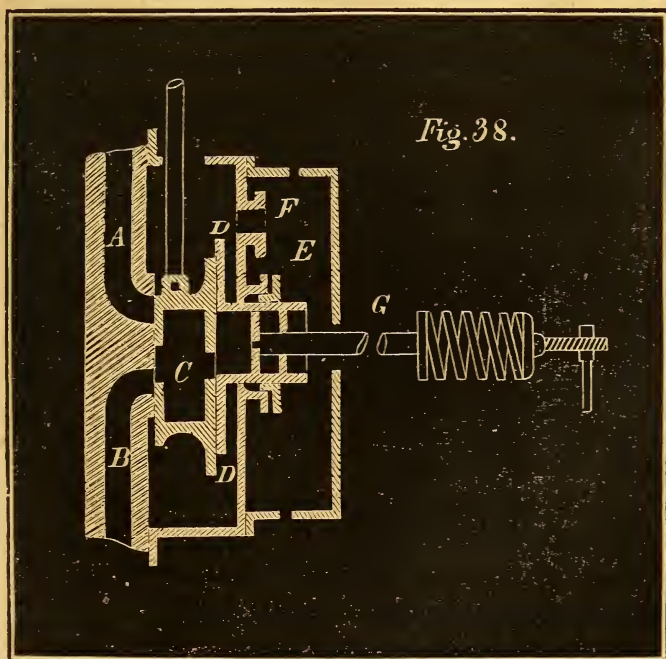


pipe connecting the interior of the ring with the condenser. By this means, as there is a vacuum within the ring, the pressure is taken off so much of the back of the valve as the ring encloses. The ring is sometimes secured to the back of the valve, instead of to the steam chest. But the arrangement indicated in the figure is the best, since the ring can readily be adjusted at any time by the set screws, whereas, when the ring is secured to the valve, the bonnet of the steam chest must be removed to set up the packing. Instead of the pipe D, a hole might be cut through the back of the valve, opening communication with the exhaust port, and so taking the pressure off the back. But by this arrangement we

could not tell whether the ring leaked or not. In the present case, however, by removing the pipe or breaking a joint, we can see at once whether any steam escapes past the ring.

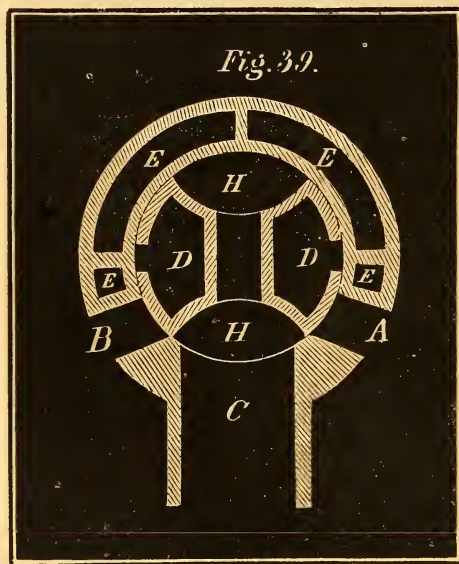
Bristol's roller valve has been applied to government vessels to a great extent. It is a common three-ported valve, and is not balanced, but the pressure on the back is taken on steel rollers working on steel seats on the face. This valve seems to give satisfactory results.

The box valve is like a box with or without a top, having an opening in it equal to a large proportion



of the area of the valve. A valve of a similar character, but possessing several novel features, is represented in Fig. 38. A and B are the ports, communicating with the two ends of the cylinder. The valve C is open on the inside, and works steam-tight against a back, D. The opening in the centre of the valve is the exhaust port, and communicates directly with the condenser E. The backing D is connected with the exhaust pipe, and can be kept up against the valve by means of the screw and spiral spring. F is the steam pipe passing through the condenser. The action of this valve will be apparent.

The piston valve consists of a pipe having a piston



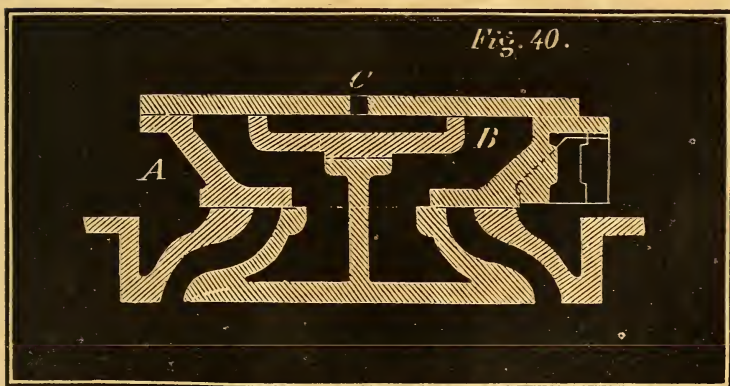
at each end, working in a cylindrical valve chest. The opening in the pipe forms the exhaust port. This is also an equilibrium valve.

Fig. 39 shows a cross section of a balanced valve, partaking of the nature of a plug cock. A and B are the steam

ports, and C is the exhaust. The steam enters the

spaces D D of the valve through the openings E E E E, and when the valve is made to oscillate, steam is admitted at one end, as B from D, and escapes from the other end, as A through the exhaust opening H into the exhaust port C. It will be seen that the upward and downward pressures of the steam in the spaces D D are the same; also that, as there is an opening, H, on the top of the valve corresponding to and connected with the lower opening H, the exhaust portion of the valve is in equilibrium. Theoretically this is a very good style of valve, but in practice it is found impossible to keep it tight. All those who remember the great trouble and enormous expense caused by rotary valves on the "Adriatic," will concur in condemning them.

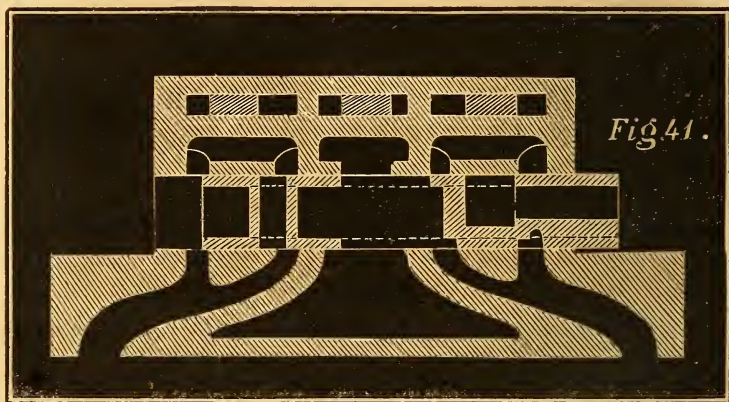
Waddell's balanced valve, Fig. 40, has a ring, B,



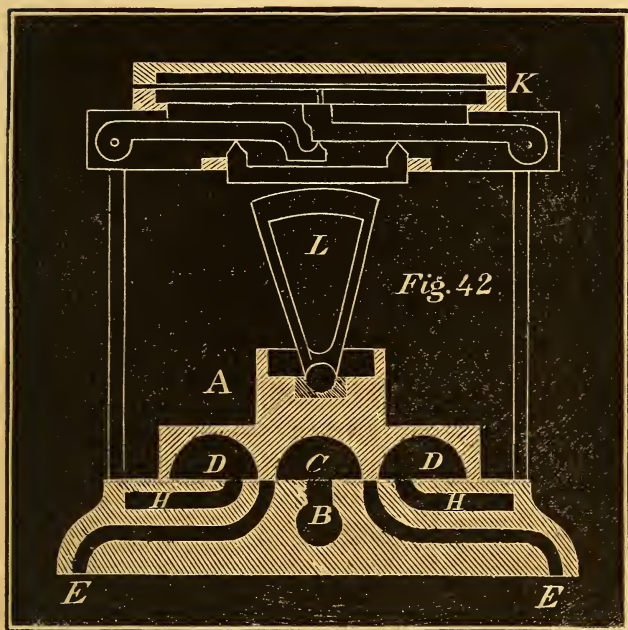
under the top of the valve, instead of on the top. By this means there is an upward pressure on the

valve, to relieve so much of the downward pressure as is not balanced by the steam ports and the channels in the valve seat.

The valve of the U. S. Steamer, "New Ironsides," is double-ported, and slides under a saddle-plate, so that the pressure is taken off the back. It is represented in Fig. 41. The lower side of the valve work on steel rollers, so as to relieve the weight.



Davie's balanced valve, Fig. 42, presents the novel feature of a valve working in the open air without any steam chest. B is the steam pipe, and C the steam opening in the valve, D D are the exhaust openings, and H H the exhaust ports. E E are the cylinder ports. The pressure under the valve is relieved by steam in the chamber I, acting by means of the flexible diaphragm K on levers and rods pressing against the sector L.



§ 14. *Saturation of water in marine boilers, scale, and the means of preventing its formation.*

The proportion of saline matter held in solution in sea water is from 32 to 38 parts in 1000. Deep sea water, from whatever locality, holds nearly the same constituents in solution, containing, on an average, in 1000 parts, according to Dr. Ure :

- 25. Chloride of Sodium,
- 5.3 Sulphate of Magnesia,
- 3.5 Chloride of Magnesium,

0.2 Carbonates of Lime and Magnesia,
0.1 Sulphate of Lime.

Besides a little sulphate and muriate of potash, iodide of sodium, and bromide of magnesium.

The principal ingredient of the substance called scale, which is formed in boilers using sea water, is sulphate of lime. Where spring water, or what is commonly known as hard water, is used, carbonate of lime is the principal ingredient of the scale. It will be observed, by a reference to the analysis of sea water, that it contains but a small proportion of sulphate of lime. It is supposed, however, that when the water in the boiler assumes a high temperature, the sulphate of magnesia is decomposed, and that the sulphur, uniting with lime, forms scale. It is also a fact, that the power of water to hold salts of lime in solution decreases as the temperature increases, and that is one reason why boilers carrying high steam will form so much more scale than those where the pressure is less, each boiler evaporating the same amount of water in a given time. As to the injurious effects of incrustation, it is enough to know that the conducting power of iron is about thirty times that of scale, to say nothing of the liability of burning the iron, when an excessive deposit of scale takes place. Should the water attain the concentration of $\frac{12}{32}$, it will form a saturated solution, and common salt will be deposited.

When sea water is used for the purpose of gene-

rating steam, it is very evident that if this process were continued for any length of time, the result would be, that the boiler would soon contain nothing but one mass of saline matter, and the crown sheets, flues, tubes, and connections becoming highly heated, would be destroyed, and the boiler rendered worthless. To prevent this injurious effect, every marine boiler is provided with what is termed a blow valve, by means of which a portion of the water is occasionally blown out, or the blow valve is kept partially open all the time the engine is in motion, which is termed a steady blow. To determine the proper amount of water that should be blown out, to prevent scale forming to an injurious extent, and also to prevent any needless expenditure of fuel, marine boilers are provided with an instrument termed a salinometer. This is represented in Fig. 43, as usually con-



structed. It is made of glass in the form represented. The slender neck of the instrument is graduated, and shows the proportion of saline matter contained in the water by the depth to which it sinks. Thus, if the point marked $\frac{1}{32}$ stands at the surface of the water, we know that the saline matter is in the proportion of 1 to 32 by weight, and so on.

Salinometers are also made of brass, and these are more delicate than the glass instruments. It is well to have one of them on board a steamer to use as a test for the glass salinometers, as these are rarely graduated with perfect accuracy.

There is another point that must also be considered. Water at different temperatures varies in density, becoming lighter as the temperature increases. For this reason the salinometer is graduated for a fixed temperature, generally 200° Fahrenheit, and a thermometer is used in connection with it, so that the water tested may be of the proper temperature. But if the water varies a few degrees from the standard, we can allow for it by making a correction of $\frac{1}{8}$ of $\frac{1}{32}$ for every 10°, adding the correction if the temperature is greater than 200°, and subtracting if it is less.

It will be observed in the figure, that the divisions on the graduated scale are constantly decreasing. This is so, because, as the saturation increases, there is more of the slender neck out of the water requiring to be supported, and less of the instrument immersed to support it. We will now explain the method of

graduating a salinometer. This will sometimes be found useful on board ship as a test. The instrument is first put into distilled water at the temperature of 200° , and the point o , or F W noted. It is then put into sea water at the same temperature, and the point $\frac{1}{32}$ noted. This water is then boiled down to half its bulk, and the point $\frac{2}{32}$ noted, and so the operation is continued.

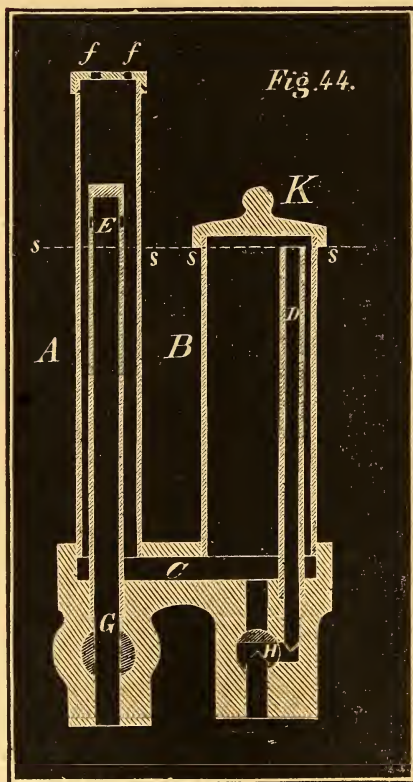
The thermometer and barometer can be employed to ascertain the saturation of the water in the boiler. The boiling point of water increases with the density, and by observing the temperature at which water drawn from the boiler boils in the open air, its saturation is made known.

Annexed is a table of the boiling points of water at different densities.

Density.	Boiling Point.
$\frac{1}{32}$	213.2°
$\frac{2}{32}$	214.4°
$\frac{3}{32}$	215.5°
$\frac{4}{32}$	216.7°
$\frac{5}{32}$	217.9°
$\frac{6}{32}$	219.1°
$\frac{7}{32}$	220.3°
$\frac{8}{32}$	221.5°
$\frac{9}{32}$	222.7°
$\frac{10}{32}$	223.8°
$\frac{11}{32}$	225.0°
$\frac{12}{32}$	226.1°

Fresh water boils in the open air at a temperature of 212°.

To use the salinometer as a test of the saturation of the water in a boiler, a pot is usually attached to the boiler, so that water can be let into it and a salinometer placed therein. As a specimen of a very complete and useful pot, Mr. R. H. Long's deserves a notice.



This is represented in Fig. 44. We copy from the inventor's explanation. "This improvement consists in attaching the cylinder A to the cylinder B, having a communication C, as a means of safety to the hydrometer, perfect accuracy in testing the density of water, and insuring the engineer against danger from scalding, etc.

The cylinder, or other shaped vessel A, is connected with the boiler by the pipe and stop-cock G, the

pipe G being closed at the top and having openings on the side near the top E E.

The water coming from the boiler and passing the stop-cock G, makes its exit through the openings E E; at this point the steam is liberated from the water and escapes through the openings *f f*, the water falls into the cylinder A, passes through the opening C, and rises to the water level *s s s s* in both cylinders. D is an overflow pipe to carry off the surplus water, and to keep up a sufficient current to maintain the water to be tested at the required temperature. By turning the stop-cock H, both cylinders can be discharged.

This instrument affords a ready means of drawing water from a steam boiler under any pressure and temperature, without ebullition in the cylinder B, or oscillation to the hydrometer.

Now let us consider the quantity of water necessary to be blown off, to keep the water in the boiler at a certain point of saturation. Suppose the saturation of the water entering the boiler is $\frac{1}{32}$, and that we are maintaining the saturation of water at $\frac{2}{32}$. Then, as the saturation of the water is doubled, one-half of it must have been evaporated. So, to carry the water at $\frac{2}{32}$, as much must be blown out as is converted into steam.

Suppose the required saturation of the water is $\frac{3}{32}$, then, since the saturation of the water in the boiler is trebled, it must have received $\frac{2}{32}$ from the evapor-

ated water; so that in this case, we blow off $\frac{1}{3}$ of the water that enters the boiler.

Similarly, we may show that,

If required saturation = $\frac{4}{3\frac{1}{2}}$, water blown off = $\frac{1}{4}$ of water entering the boiler.

If required saturation = $\frac{5}{3\frac{1}{2}}$, water blown off = $\frac{1}{5}$ of water entering the boiler.

If required saturation = $\frac{3\frac{1}{4}}{3\frac{1}{2}}$, water evaporated = $\frac{3}{4}$ of water blown off.

If required saturation = $\frac{1\frac{1}{2}}{3\frac{1}{2}}$, water evaporated = $\frac{1}{2}$ of water blown off, etc., etc.

Besides the practice of blowing to prevent the formation of scale, other means are sometimes employed, and we will briefly notice a few of them.

The sulphate of lime causes the most trouble. Crushed potato is a mechanical preventive. The pulp is supposed to cover the crystals of sulphate of lime, and separate them so that they cannot form a continuous mass. Chemical preventives are numerous; but the great objection to them is, that they injure the iron of the boiler. Muriate of ammonia, or sal ammoniac, put into the boiler daily, in small quantities, acts in the following manner: The carbonate of lime is decomposed, the muriatic acid in the sal ammoniac combines with the lime, keeping it in solution, and the carbonic acid, uniting with the ammonia set free, forms carbonate of ammonia, which passes off with the steam.

But the sal ammoniac has no effect upon the sulphate of lime.

Another remedy for the carbonate of lime incrustation, is quick-lime. This changes the bicarbonate of lime, which is soluble into the insoluble carbonate, and this latter can be removed from the boiler at such times as are convenient.

A preparation of tobacco in the form of a liquid has been used in marine boilers. This does not prevent the formation of scale, but renders it soft, so that it can be swept off or washed away with a stream of water from a hose. This has not received a very thorough trial, but as far as known it does not injure the iron. It is objectionable when the water for use on board ship is distilled from the boilers, for the liquid also evaporates and gives the water a very unpleasant taste.

Another method of preventing scale, is by the use of a compound which removes the saline matter from the water before it enters the boiler. This would seem to be the best method of all, and the experiments upon it have been very satisfactory. But for some reason it has hitherto failed to be introduced.

Chloride of barium will prevent the sulphate of lime incrustation, and it is said not to have an injurious effect upon the iron of a boiler. It is a chemical preventive, and decomposes the sulphate of lime, forming chloride of lime, which continues in solution, and sulphate of barium, a heavy powder, which is precipitated as a kind of slush in the bottom of the boiler.

When this preventive is used, and we haul fires

to clean a boiler, all the water must not be blown out before it is cool, or the precipitate will harden. When the hand holes are removed, the sulphate of barium can readily be cleaned out.

§ 15. *Condensers and Feed Water Heaters.*

In condensing engines, the steam is condensed (when it exhausts), either by being brought into contact with a jet of cold water, as in the case of a common jet condenser, or by passing through or around a series of tubes, made cool by water being passed around or through them, which is the action when a surface condenser is employed. When a jet condenser is used, salt water is pumped into the boilers; but a surface condenser, if tight, saves the fresh water derived by condensation, and it can be returned to the boilers again and again. By this means nearly all the feed water is fresh, and but little blowing off is required to keep the water at a certain point of saturation. A calculation of the loss by blowing off will show us the gain derived from fresh water condensers, supposing them to be tight, and to condense all the steam used by the engines. We will show the method of calculating the loss by blowing off.

The number of degrees of heat that must be imparted to the water converted into steam, will be the number in the total heat of the steam, minus the number of degrees in the feed water. The heat lost

by blowing off will be the difference between the temperature of the feed water and the sensible heat of the steam. A comparison of this loss with the entire number of degrees of heat required, being the sum of the heat imparted to the steam, and that to the water blown off, will give the per cent. of loss.

EXAMPLES. — 1. What is the per cent. of loss by blowing, where we carry the water at a saturation of $\frac{3}{32}$, with 20 pounds pressure per steam gauge, the feed water having a temperature of 110° ?

To carry the water at a saturation of $\frac{3}{32}$, twice as much is converted into steam as is blown off.

Sensible heat of the steam = 260° .

Total " " " = $1193^{\circ}.45$.

$1193^{\circ}.45 - 110^{\circ} = 1083^{\circ}.45 =$ degrees of heat imparted to the water converted into steam.

But as twice as much water is made into steam as is blown off,

$1083^{\circ}.45 \times 2 = 2166^{\circ}.9 =$ degrees of heat producing useful effect, for every $260^{\circ} - 110^{\circ} = 150^{\circ}$ heat lost by blowing off.

$2166^{\circ}.9 + 150^{\circ} = 2316^{\circ}.9 =$ total quantity of heat imparted to the water. Therefore,

$(100 \times 150^{\circ}) \div 2316^{\circ}.9 = 6.47$ per cent. of heat lost by blowing off.

2. What is the per cent. of heat lost carrying the water at $\frac{13}{32}$, the other data being the same as in the preceding example?

Here only $\frac{3}{4}$ as much water is converted into steam as is blown off, so that

$1083^{\circ}.45 \times \frac{3}{4} = 812.58 =$ heat producing useful effect for every 150° lost by blowing off.

$812.58 + 150 = 962^{\circ}.58$, total heat imparted to the water.

$(100 \times 150^{\circ}) \div 962^{\circ}.58 = 15.58$ per cent. of heat lost.

The water that is blown off is sometimes passed through heaters, by which the temperature of the feed water is increased. By this means there is a gain in fuel, as the total quantity of heat imparted to the water is not so great as when the temperature of the feed water is less.

EXAMPLES. — Find the per cent. of heat saved in the two preceding examples, supposing the feed water to have a temperature of 160° , instead of 110° .

1st. When the feed water has a temperature of 160° , and the saturation is maintained at $\frac{3}{32}$,

$(1193^{\circ}.45 - 160^{\circ}) \times 2 = 2066.9 =$ heat imparted to two parts of water converted into steam.

$260^{\circ} - 160^{\circ} = 100^{\circ} =$ heat imparted to one part of water blown off.

$2066^{\circ}.9 + 100^{\circ} = 2166.9 =$ total heat imparted to the water.

$2316.9 - 2166^{\circ}.9 = 150^{\circ} =$ gain by use of heater.

$(100 \times 150^{\circ}) \div 2316.9 = 6.47 =$ per cent of gain.

2d. When the saturation is maintained at $\frac{13}{32}$,

$(1193^{\circ}.45 - 160^{\circ}) \times \frac{3}{4} = 775.08 =$ heat imparted to $\frac{3}{4}$ of a part of water made into steam.

$260^{\circ} - 160^{\circ} = 100^{\circ} =$ heat imparted to one part of water blown off.

$775^{\circ}.08 + 100^{\circ} = 875^{\circ}.08 =$ total heat imparted to the water.

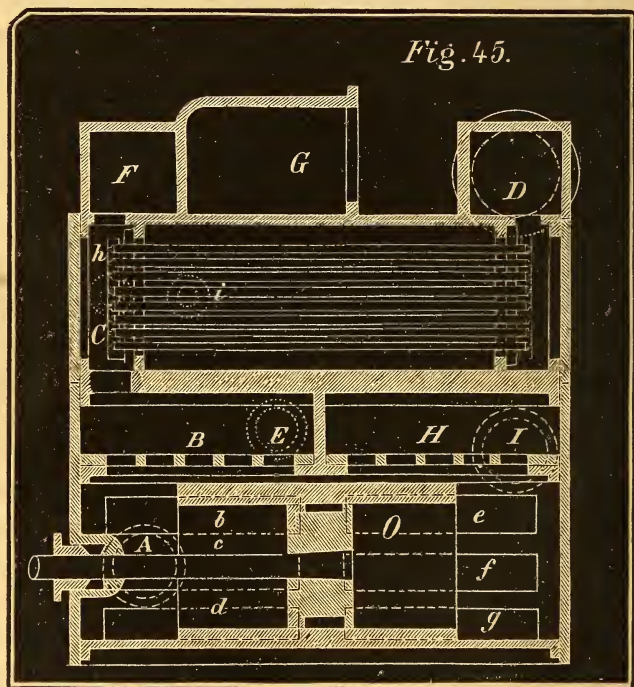
$962^{\circ}.58 - 875^{\circ}.08 = 87^{\circ}.5 =$ gain by use of heater.

$(100 \times 87^{\circ}.5) \div 962^{\circ}.58 = 9.09 =$ per cent. of gain.

In practice the gain by the use of surface condensers is not as large as the theoretical result. Nearly all such condensers leak to some extent, so that salt water mingles with the water of condensation. Moreover, all the water that is evaporated by the boilers is not preserved in the condenser, so that a salt feed is necessary from time to time. Surface condensers are also much heavier, and occupy about twice as much room as the old jet condensers. Their first cost, and the numerous repairs they require, must be considered. The vacuum also is not generally as good as that produced with jet condensers. It has been found too that surface condensers have a powerful influence in causing the corrosion of boilers. Still, with all these drawbacks, the advantages of surface condensers have been considered so great, that they have been largely introduced. The most successful types have been Pirrson's and Sewell's. In Pirrson's condenser the exhaust steam passes through a number of tubes, and is condensed by a shower of cold water around the tubes. There are two pumps,

one for the condensed, and the other for the injection water, so that there is a vacuum, both within and without the tubes. There is a communication between the fresh and salt water sides, so that the vacuum is the same in each. The tubes of this condenser are secured to one tube head, but pass through the other one, which is double, with a rubber diaphragm between the two parts. By this means each tube is allowed to expand and contract without causing leaks.

Sewell's condenser is represented in Fig. 45. The



air pump O is double-acting, and has two sets of foot and delivery valves, one set being for the injection, and the other for the condensed water. The injection water enters at the opening A, is drawn through the foot valves *b c d*, and forced through the delivery valves B, through the tubes C, and overboard through the outboard delivery D. The exhaust steam enters at G, and is condensed by contact with the outer surfaces of the tubes. The water of condensation is drawn through the foot valves *e f g*, and is forced through the delivery valves H, and the outboard I, into a reservoir, from which the feed pumps draw their water. There is a loaded valve in this reservoir, communicating with the outboard delivery, so that, when the reservoir becomes full, the water may escape. The openings *h i* are the ends of a pipe connecting the fresh and salt water reservoirs, so that any deficiency in the feed water may be supplied from the latter reservoir. F is an air chamber for the salt reservoir, and E is the end of a pipe through which the auxiliary pump draws water. The tubes in this condenser are not secured to the tube heads, but pass through them, and are made tight by rubber grummetts. By this means each tube is allowed to expand and contract independently of all the others.

Lighthall's patent refrigerator, though not a surface condenser, is intended to keep the water in the boilers fresh. A common jet condenser is employed, and the refrigerator is placed on the side of the vessel. By the motion of the ship a stream of cold water is

continually passing through a series of long tubes. The discharge water passes around these tubes, and being cooled is used again for injection water; is returned to the refrigerator cooled, and used over and over. So if the boilers are filled with fresh water when fires are started, the only salt feed required will be to supply the water lost by leaks.

Before leaving the subject of condensers, we will consider the amount of injection water required to condense steam of a given temperature. The injection water enters the condenser at a certain temperature, and coming in contact with the steam, its temperature is increased, and that of the steam diminished, all the latent heat of the steam being made sensible. So we have only to find how large a quantity of water will be required to contain all the heat in the steam.

EXAMPLE.—What is the relation between the injection water and water of condensation, the total heat of the steam entering the condenser being $1188^{\circ}.09$, the temperature of the injection water 60° , and of the discharge water 110° ? As the water of condensation has a temperature of 110° , there are $1188^{\circ}.09 - 110 = 1078^{\circ}.09$ of heat imparted to the injection water. But a quantity of injection water, equal to the water of condensation, receives $110^{\circ} - 60^{\circ} = 50^{\circ}$ of heat. Hence, the quantity that receives $1078^{\circ}.09$ of heat will be $1078^{\circ}.09 \div 50^{\circ} = 21.56$ times the water of condensation.

When a ship springs a leak, if it is at all serious,

the bilge injection is generally used to aid in removing the water from the hold. We will take an example, to show how much may be accomplished in this way.

EXAMPLE. — How many cubic feet of water could be removed from the hold of a vessel by the use of the bilge injection, under the following circumstances: diameter of cylinder, 60 inches; length of stroke, 10 feet; pressure of steam per gauge, 25 pounds; revolutions per minute, 16; temperature of water in hold, 70° ; temperature of discharge water, 95° ; the steam being supposed to follow $\frac{3}{4}$ of the stroke, and the clearance being disregarded?

19.635 square feet = area of piston.

$19.635 \times 7.5 = 145.26$ = cubic feet of steam used each stroke.

$145.26 \times 32 = 4647.39$ = cubic feet of steam used per minute.

$4647.39 \times 60 = 278843.4$ = cubic feet of steam used per hour.

The relative volume of steam and water, at a pressure of 25 pounds, is 679, so that

$278843.4 \div 679 = 410.7$ cubic feet of water evaporated per hour.

$1195^{\circ}.84$ = total heat of steam.

$1195^{\circ}.84 - 95^{\circ} = 1100^{\circ}.84$ of heat imparted to injection water.

$95^{\circ} - 70^{\circ} = 25^{\circ}$ of heat imparted to one part of injection water.

$1100^{\circ}.84 \div 25^{\circ} = 44.04$, relative quantity of injection water necessary to produce one part of condensed water. Hence,

$410.7 \times 44.04 = 18087.23$ cubic feet of water that can be removed from the hold in an hour.

$18087.23 \times 62.5 \div 2240 = 504.66$ tons.

§ 16. *Relation of power (or fuel) and speed in steam navigation.*

The resistance experienced by a ship to its motion is composed of the resistance of the atmosphere and that of the water. The general case of the resistance of the atmosphere can scarcely be computed, on account of the varying circumstances of the weather, and the different conditions under which the ship is considered, as regards the sail carried. The resistance of the water, however, is represented by a constant law, increasing as the square of the velocity of the vessel. This result is established both by experiment and theory. The theory of the resistance is, that the particles of water are displaced by the vessel with a velocity equal to the ship's speed, the power required to displace them varying directly as the velocity; so that the resistance, which is the product of the power required to displace the water, and the velocity with which it is displaced, will vary as the square of the velocity. Thus, if the speed of the vessel is 2 knots per hour, the resistance is as 4, and if the speed of the vessel is only in-

creased 1 knot, the resistance is as 9. These numbers, it will be understood, only express the relations between the resistance offered to the ship at different speeds, and not the actual resistance. The resistance evidently cannot act on the entire midship section of a vessel, else the paddle boards or propeller—the area of either of which is very small, as compared with the midship section—would not be available. The shape of a vessel determines the amount of section resisted by the water; and a vessel that moves through the water with little displacement of the particles, as will be the case if the bow is very sharp, will experience less resistance than another vessel of the same midship section, but displacing the particles of water more abruptly. Still, with a ship of a given form, the resistance varies as the square of the vessel's velocity. The density of the water also has an influence on the resistance. A vessel moving through salt water will experience more resistance than if the water were fresh, if the immersion is the same in both cases. But as salt water is more buoyant than fresh water, the immersion of a vessel coming from fresh to salt water is diminished, so that the resistance to its motion is unaltered.

To determine the amount of section resisted by the water, with vessels of various forms, belongs rather to the shipbuilder than the engineer. So we will content ourselves with the relations, after the form of a vessel is determined.

We will now consider the power necessary to in-

crease a vessel's velocity. This, as shown both by theory and experiment, varies as the cube of the velocity. We may explain it in the following manner: As the increased speed of the ship requires the speed of the engines to be increased in direct proportion to the velocity, and as the resistance to be overcome varies as the square of the velocity, the power developed by the engines, which is the product of their speed and the resistance to their motion, varies as the cube of the velocity. So, if we make the speed of a ship twice what it was originally, the resistance will be four times as great, and the power required will be eight times that originally employed. Now the fuel consumed has a direct relation to the power developed, so that we can find the power or fuel necessary to increase the speed of a vessel, when we know the original conditions.

EXAMPLES. — 1. Suppose a vessel, consuming 25 tons of coal per day, and developing a power of 500 horses, has a speed of 9 knots; what fuel and horse-power are required to give the vessel a speed of 11 knots?

According to the law, that the power varies as the cube of the velocity,

$$9^3 : 11^3 :: 500 : 912.9, \text{ required horse-power.}$$

Or,

$$9^3 : 11^3 :: 25 : 45.6 \text{ tons of coal required per day.}$$

2. From the fact that it requires such a large increase of power and fuel for a very slightly augmented

speed, it is evident that we can effect a great saving by reducing the speed a little. This is a matter of great importance, and one worthy the attention of engineers.

Suppose we wish to reduce the consumption of coal from 30 to 20 tons per day, what will be the difference of speed, supposing the vessel to make 12 knots an hour, when burning 30 tons of coal per day?

For this case we shall have the proportion :

$$30 : 20 :: 12^3 : 10.5^3.$$

Hence the speed will be reduced $1\frac{1}{2}$ knots, or $\frac{1}{8}$, while we effect a saving in fuel of $\frac{1}{3}$.

It is found by experiment that large vessels have greater speed than small ones, both ships having the same model, and each having power proportioned to its size. The increase of speed appears to vary as the square root of the length of the vessel. Thus, if there are two vessels of the same model, one of them having four times as much capacity and power as the first, and being, therefore, twice as long, the speeds of the two ships will vary as the square root of 2 to the square root of 1, or the large vessel will be $1\frac{3}{4}$ times faster than the small one. But this is also a question for shipbuilders, and we will not enlarge upon it.

When steaming against a current, the speed of the vessel should be once and a half as great as that of the current, so that the vessel may have an effective

speed half as great as that of the current. This rule also accords with theory and experiment. If we know the velocity of the current, the difference between that and the speed of the ship will be the effective speed. The power required to propel the ship will vary as the cube of the actual speed of the ship. The power required to propel the ship one unit of space, or one knot, will vary as the cube of the actual speed, divided by the effectual speed. Our object is to make this power as small as possible, and we will find it to be so, when the speed of the ship is once and a half times that of the current.

EXAMPLE. — Suppose there is a current running at the rate of 6 knots an hour, opposed to the motion of the vessel. What speed should the ship have to develop the least power?

According to the law, 9 knots should be the speed of the ship, but we will try other speeds, and see which requires the least power.

For a speed of 9 knots,

$$9 - 6 = 3 = \text{effective speed of ship.}$$

Power required to produce this speed varies as 9^3 , or 729.

Power required to propel the vessel a distance of one knot varies as $729 \div 3$, or as 243.

For a speed of 10 knots,

Power required to propel the ship one knot varies as $10^3 \div (10 - 6)$ or as 250.

For a speed of 11 knots,

Power required to propel the ship one knot varies as $11^3 \div (11 - 6)$ or as 266.2.

So we see that the required power continually increases for a speed greater than 9 knots. Let us try a less speed.

For a speed of 8 knots,

Power required to propel the vessel one knot varies as $8^3 \div (8 - 6)$ or as 256.

For a speed of 7 knots,

Power required varies as $7^3 \div (7 - 6)$ or as 343.

Hence we see that the law enunciated before holds good in giving us the most economical speed for steaming against a current.

§ 17. *Management of Engines and Boilers at Sea.*

After the engines, boilers, and their attachments have been placed in a vessel, and the ship has been accepted from the contractors, the duties of the engineer commence. He is expected, as far as possible, to keep the machinery in proper condition, and to use every available means to make necessary repairs. The old adage, "A stitch in time," is very applicable in this case. There have been cases where, by the negligence of an engineer in not securing a nut in its position, cross heads and cylinder covers have been broken.

While it is impossible for any one to enumerate

all the things that require an engineer's attention, we may note down a few of the most important. So let us go on board the vessel, get up steam, and make a passage.

If the boilers are new, we shall probably find a quantity of bolts and rivets in the legs. As many as possible of these should be removed before the boilers are filled. At all events, be the boilers new or old, the braces should be examined, to see if they are properly set up, and that no brace pins are left out. The man and hand-hole plates should then be put on, the safety-valve raised, and the boilers filled with water. If the water line of the boilers is below that of the vessel, by opening the bottom blow, the water will enter; otherwise the hand pump must be used. (The safety-valve is raised before filling the boiler, to let the air escape as the water enters.)

Before wooding the furnaces, a thin layer of coal should be thrown over the grate bars, or at any rate over the back bars. The wood is then put in, and at the mouth of the furnaces should be placed all the oily waste that has been used for cleaning purposes. We are now ready to raise steam whenever required, as far as the boilers are concerned.

Let us turn our attention to the engines. All keys, glands, and set screws should be carefully examined, to see if they are properly adjusted. All tools, blocks of wood, etc., that have been used around the engines, should be put away. Wicks should be put in all the oil cups, unless glass syphons (which

of late have been much used to supply oil to the journals) are employed. The finished work of the engines, except such as can readily be cleaned when under way, should then be covered with a mixture of white lead and tallow, in the proportion of 3 parts of tallow to 1 of white lead.

When the order is given to raise steam, the fires should be started, and allowed to burn at a moderate rate, and at least three hours should be occupied before steam is generated. When the fires are forced, there is great danger of injuring the steam chimney and other parts of the boiler above the water level, for it must be remembered that there is nothing but air surrounding these parts before steam is raised. It is a good rule not to spread the fires until steam commences to form.

The safety-valve should be kept open until steam begins to escape, so that the air may be expelled from the boiler. As soon as steam is generated, lower the safety-valve, and when there is a sufficient pressure, proceed to warm the engines. (The stop valves may be opened, either before starting fires, or when steam is raised.) To do this, open the out-board deliveries and the sea valves, work the pistons back and forth a few times by means of the pass-over valves, starting bar, or links, as the case may be, and then let the engines make a few revolutions, opening the injection valves for the purpose of producing a vacuum, and freeing the cylinders of water by means of the water valves, when these are fitted.

If everything appears to work well, stop the engines, feed all the oil cups; and the engines are ready for operation.

When the engines are in motion, the first care of the engineer should be for the boilers, to see that the water is carried in them at a proper height; that the required pressure of steam is maintained; and that the density of the water does not go beyond a given point. For these purposes, spring and syphon steam gauges, gauge or test cocks, glass gauges, and salinometers are provided. As regards the quantity of water in the boilers, too much reliance should not be placed on the glass gauges, but the gauge cocks should be frequently opened. It often happens that glass gauges become stopped up, or the cocks connecting them with the boilers are accidentally shut, so that it may be very dangerous to trust to them. They are usually so arranged that they can be blown through and cleared, and it is well for each engineer, when coming on watch, to blow them through, and assure himself that they are in working order.

To keep down the saturation of the water, a portion must be blown off, either at certain intervals or continuously. The latter method is the best, since the saturation can be kept at one point, instead of varying, as it must do, if we only blow at intervals. The saturation should be tested at least once an hour. It is a good plan to keep up a constant circulation of water in the salinometer pots, so that we have only to glance at the salinometer, and we can

ascertain the saturation as readily as we can find the height of water in the boilers.

To maintain the required pressure of steam, we are, in a great measure, dependent on the firemen. Every minute that a furnace door is kept open is of great consequence; so that quickness is a most important characteristic of a good fireman.

Experience in firing is undoubtedly the best teacher, but a few general remarks may not be out of place.

From eight to twelve hours after fires have been started, it becomes necessary to clean them, otherwise the clinker and ashes will accumulate in the furnaces, putting out the fires. When fires are cleaned, it takes from fifteen to twenty minutes for them to burn up; so that only one fire should be cleaned at a time, and not more than one-third of the entire number in a four-hour watch. By this means each fire will be cleaned every twelve hours, which is sufficient when using coal of fair quality. But to the operation. The fireman, after providing himself with the necessary tools, deposits a quantity of ashes in front of the furnace, pushes the fire back or to one side, removes the clinker from the grate bars, and with a hoe draws it, together with the ashes, out of the furnace. For pulling out very large pieces of clinker, a rake is often used. The fireman then pulls the fire forward, or pushes it to the other side of the furnace, and removes the rest of the clinker and ashes. The fire remaining in the furnace

is now levelled and covered with coal. It is evident that the more quickly this operation can be performed, the less will it affect the pressure of the steam. A very reprehensible practice is generally resorted to, to protect the fireman from the heat. A stream of water is turned on to the dirt and clinker as they are drawn from the furnace. This water at first forms steam, and drives the fireman away from the furnace, thereby causing the door to be kept open longer than it otherwise would. Moreover, the water has a very injurious effect upon the legs and ash pans. If, as the dirt is drawn from the furnace, one of the men throws dead ashes upon it, it will be smothered, and can be wet down when the fire is cleaned.

Firemen, unless prevented, are in the habit of letting the fires burn too low before cleaning them, for the reason that the operation can be performed much more easily. But when such a fire is cleaned, it will nearly go out, and a long time will elapse before it will be effective.

The fires, to produce the greatest effect in making steam, should not be more than eight inches in thickness. No two furnaces should be fired at the same time, and, generally, no two furnace doors should be open at the same time. The fires should be kept bright underneath, all the ashes being removed by means of the pricker. No pieces of coal should be put into the furnaces that are larger than a three inch cube.

All the ashes should be hoisted before the end of the watch, and a reasonable quantity of coal left on the floor for the relief.

Boilers with little steam room, or with heating surfaces so arranged that steam cannot readily escape, are very liable to foam. In the first case the agitation or lifting of the water seems to be caused by its having a greater temperature than the steam, and in the second case the water appears to be carried up mechanically with the steam, as it rises to the surface. All boilers are apt to foam when there is mud or dirt of a mucilaginous nature in the water. Changing the water in a boiler from salt to fresh, or from fresh to salt, is also a frequent occasion of foaming. So this is an occurrence for which the engineer must be on his guard. Foaming is made evident by the boiling up of the water in the glass gauge, and by its issuing from the gauge cocks as a mixture of steam and water. In cases of violent foaming, the water will be carried over into the cylinders, which will be made evident by the thumping at each end of the stroke, and by the breaking down of the engines, if the water is not blown out.

When this foaming occurs, it is desirable to change the water in the boilers, and make it all of one kind, either salt or fresh, as quickly as possible. So we should put on a strong feed and blow, and also partially close the throttle to check the agitation of the water. As the water has a greater temperature than the steam, it is sometimes advisable to open the

furnace and connection doors. By the employment of these means, foaming can be soon suppressed in well-proportioned boilers.

Foaming is sometimes caused by having too much water in the boiler, whereby the steam room is reduced. So this should be guarded against.

In boilers with insufficient steam room, foaming cannot be entirely suppressed, except by mechanical means—such as dry pipes, diaphragms, and the like. But by working the steam expansively and throttling, much of the foaming may be stopped. Where boilers only lift the water, but do not carry it into the cylinders, the only remedy seems to be to close the throttle almost entirely, at short intervals, so that the actual height of the water can be ascertained.

Should the water in a boiler get low by accident, and the engineer is in doubt as to its condition, no time should be lost in hauling fires, closing the stop valve of that boiler, and shutting the valve by which the water is escaping. In such a case the feed should not be put on, as it may lead to fatal consequences. After a sufficient time has elapsed for the boiler to cool, water may be admitted and fires started once more.

Should a tube burst in a vertical tubular boiler, and leak to a serious extent, fires must be hauled from that boiler, the stop-valve closed, the water blown out, and the boiler entered to plug the tube. After the tube is found, we have only to drive a pine plug into each end. The greatest trouble is to find

the tube. A tolerably effectual way of making the discovery is as follows: stop up the front and back ends of the tube box for a height of three or four inches, and fill this space with water. Then, by looking into the boiler, we can see if there are any leaks in the lower ends of the tubes. A leak in the top of a tube can generally be found, when there is water in the boiler, by putting a lamp or a piece of waste saturated with turpentine between the tubes near the upper tube sheet.

Should it be a horizontal tube that requires to be plugged, it can readily be seen at the front end, and can be stopped with a pine plug. To stop the leak in the back connection, the fire under the tube box that contains the faulty tube must be hauled, so that the back connection can be entered, and the tube plugged. This is rather warm work, but it can be done. An iron plug should be used for the back end of the tube.

If all the fires in a boiler are hauled to plug up a horizontal tube, a long bolt and cup washers should be used. A pine plug should be driven into each end of the tube, with a hole through the centre for the long bolt to enter. The cup washers should then be put on, the space between them and the plugs filled with cement, and the nuts on each end of the bolt screwed up.

Should a rupture take place in the boiler, if it is not in the fire surface, and can be reached, it may be temporarily stopped by driving in a pine plug.

Otherwise, if it causes a dangerous leak, fires must be hauled until it can be repaired. But if the ship is on a lee shore, where the consequences of hauling the fires might be fatal, the fire must be hauled from the leaking furnace, and the steam worked off (so that the engine is running on a partial vacuum), when the leak can soon be stopped by shoring up a patch against the hole. The patch can be a piece of board, or anything that is convenient, for we will fill up that furnace with ashes, and throw it out of use. When this is done, the boiler is ready for steam again.

Having now noted down the principal duties of the engineer, as regards the boilers, let us turn our attention to the engines. When the engines are under way, the engineer should see that a proper amount of water is supplied to the condenser, so that the discharge water is kept at the required temperature, the proper vacuum maintained, and that the air-pump is not overloaded. A vacuum gauge is usually provided, and also a thermometer to indicate the temperature of the water in the hot well. The chief attention of the engineer, after the care of the boilers, should be given to the bearings. If the engines are in line, and the bearings are properly constructed, they will not heat, except by negligence. They should receive special attention when the engines are started, since that is the time that they are most liable to heat. As soon as a bearing shows signs of heating, a plentiful application of oil and

sulphur, or black or white lead and oil, will generally cool it. Should these means fail, water must be used, but it should be the last resort.

While the general duties of the engineer are very plain, it is impossible for any one to enumerate the thousand and one things that may occur, and the remedy suitable for each. Neither would such a course be advisable, for in an emergency it would be ludicrous, were not the consequences so disastrous, to see an engineer, book in hand, looking for the particular break down. Without doubt experience is a most valuable assistant, but presence of mind and sound common sense are also important adjuncts.

Should a water-pipe burst, it may be temporarily repaired by wrapping canvas, in strips about one inch wide, around it, securing the canvas by marline, the pipe being first covered with red-lead putty. If the pipe is very much worn, a piece of copper should be bent around it before it is wrapped, so as to increase the strength.

Feed pumps sometimes refuse to work by reason of the safety-feed being caught up, or insufficiently weighted. This should be examined as soon as a pump refuses to feed. If the feed water is very hot, vapor forms in the pump barrel, and the receiving valve cannot open. When this is the case, if there is no vapor valve fitted to the pump, it is well to slack up the gland of the stuffing box, so that the vapor can escape. Where surface condensers are employed, and tallow is used for lubricating the

cylinders, hard lumps of tallow frequently get into the pumps, and prevent their working. (The tallow also gets into the channel ways of the condenser, and it should not be used, except when absolutely necessary, and then very sparingly if a steamer has surface condensers.) Bilge pumps and auxiliary feed pumps sometimes will not draw water from the bilge for want of being charged. This can be effected, in the case of the auxiliary pumps, by letting them pump from one sea-cock to another. If, after they are charged, they still refuse to pump out the bilge, it is probably because the strainers are stopped up. The auxiliary pumps of a steamer should never be used to pump out the bilge, except in case of a dangerous leak; otherwise, they cannot be kept efficient.

Should the vacuum become impaired, all the glands of the stuffing boxes of the piston and air-pump rods, and of the expansion joints of the exhaust pipes, should be set up. We can ascertain their tightness by holding a light near them, and observing whether the flame is drawn in. If all the joints and stuffing boxes are tight, it is probable that the diminution in vacuum is caused by an insufficient supply of injection water; otherwise, there must be some derangement of the foot or delivery valves.

The condenser sometimes gets hot for want of a sufficient supply of injection water. The practice of letting a stream of cold water on to the condenser is an unskilful mode of cooling it. A much better

way is to open the bilge injection, leaving the sea injection cock also open. The vapor and steam will then escape from the condenser into the bilge, and in a few minutes the condenser will take the injection water again. As soon as the vacuum is restored, close the bilge injection.

In making a very long run it sometimes happens that the connections and flues require cleaning. In this case they can be swept without stopping the engines, one boiler at a time.

The engineer should keep a note book, in which he may put down, from time to time, such things as will need attention, when there is a chance to make repairs. By this means the labors of overhauling are systematized and made much easier.

If there is an accumulation of salt in any of the tube boxes, caused by leaky tubes, it may be cleared away by attaching a hose to the boiler, above the water level, and letting steam on to the salt.

The following cases are noted down, to show what may be done in an emergency with limited facilities.

Should the stem of a double puppet valve break between the two halves of the valve, both halves might continue to rise and seat for a few revolutions, the lower half being forced up by the pressure of the steam, and the upper half being raised by the lifting rod. But in seating the lower half would be apt to cant, so that the upper one could not seat fairly. Then the steam port would be partially open all the time, and this would be indicated by the

heating of the condenser and the sound of wire drawing steam. Such a position of affairs is not a very pleasant one, when a steamer with a single engine is in the middle of the ocean. As such a case actually occurred, it may be interesting to state the method employed to remedy the difficulty. The engine was stopped, the stop-valve of the boiler closed, and the steam blown off. The bonnet of the steam-chest was then removed, and the lower half of the valve secured in its seat by iron props, and the jagged edges of the broken stem cut off; the bonnet was replaced, and the operation was complete—the whole thing occupying a little more than an hour.

In the fall of 1862 the U. S. Steamer "Susquehanna" went on a trial trip in Pensacola Bay, and performed very satisfactorily. Just as she was coming to anchor, a dense volume of steam was observed to issue from the starboard cylinder. On removing the lagging, it was found that the cylinder had a crack extending from the bottom flange upward, a distance of a little more than eight feet, in the direction of the axis. Most engineers would have considered this too serious a break down to be repaired on board ship, and would have called for a survey. But the chief engineer, Mr. George Sewell, determined to patch the crack, and strengthen the cylinder by bands. The patches were riveted on, the rivets being driven from the inside of the cylinder, and having their heads countersunk. Bands of nearly

the right size were found among the ruins of the navy-yard, having formerly done duty as tires of the wheels of ox carts. They had to be put around the cylinder in two pieces, and then riveted together by a piece lapping over the ends, to avoid cutting the frame for the introduction of the lugs. When the patching and banding were completed, the edges of the crack were peaned together, and the leakage of steam was imperceptible. But there were more difficulties to be overcome. The cylinder was so thin in many places that it had assumed an elliptical shape, there being a difference of a quarter of an inch between two diameters at right angles to each other. The piston rod was also sprung about a quarter of an inch, and had canted the piston, so that it was not at right angles to the axis of the cylinder. The piston rod gave abundant evidence of its condition by the steam leaking through the stuffing box with a sound like that of a steam whistle. To remedy this, an external stuffing box was constructed, which worked very well. A ring was made, in two pieces, fitting the piston rod, and having lugs which were secured to the stuffing box bolts, keeping the ring about four inches away from the stuffing box. Hemp packing was tightly wound around the rod, and thus but little steam escaped. Now for the cylinder. This was planed out, the piston rings serving as cutters. Steel packing rings, tempered and with a cutting edge, were used, being set out quite hard. The engines were made to move

very slowly, for several hours at a time, until the condition of the cylinder was much improved.

This may not seem to be any great piece of engineering, and, doubtless, in a shop it would be but little thought of. The reader must remember, however, that it was accomplished with the facilities on board the vessel, and this may cause him to view the matter in another light.

During the latter part of 1862, while one of the authors of this work was attached to the U. S. Steamer "Iroquois," a serious accident occurred on the passage from the Rio Grande to Pensacola. The plunger of the air-pump, which had worn away at the centre so that the diameter was diminished seven-eighths of an inch, had such an uneven motion that the stud-bolts securing the packing gland were carried away. The gland, becoming detached, fell between the end of the plunger and the air-pump bonnet, breaking both the gland and bonnet in an irreparable manner, and cracking the channel ways in several places to a very serious extent.

The engines were immediately stopped, and preparations made to repair damages. The air-pump was double-acting, having a set of foot and delivery valves on each side of the plunger. The foot and delivery valves on the same side of the plunger as that to which the gland was bolted were removed, and the openings stopped up by bolting pieces of board to the seats. The broken stud-bolts which secured the gland were drilled out, and new ones substituted.

A new gland was made of wood, with a sheet-iron ring behind it to prevent the wood from tearing away. The broken pieces of the channel ways were replaced with putty and boards behind them, the boards being secured by jacks and shores from the ship's side. The cracks were stopped from the inside with putty, waste, and wedges. The communication valve between the fresh and salt water pumps was opened, and the repairs were complete.

The salt water pump, of course, worked single-acting, and the fresh water pump acted as an additional air-pump, so that salt water was supplied to the boilers. In this condition the "Iroquois" completed her trip to Pensacola, and from thence proceeded to New York, making a very fair passage. The whole repairs were made in twenty-four hours.

We might continue giving accounts of break downs and their remedies to an almost unlimited extent, but every engineer of much experience has a budget of such narrations. We must crave pardon for introducing the casualties that were of peculiar interest to ourselves, from the fact of our being present at their occurrence.

§ 18. *Overhauling the Engines and Boilers in port.*

When a ship arrives in port, and the anchor is down, if it is the intention to stay but a few hours, it is advisable to bank the fires. They should be first cleaned, and then pushed back, so as to leave

the front grate-bars bare. By this means the engineer has control of the steam, and avoids the nuisance of blowing off, while, with fifteen minutes' notice, he can spread the fires, and be ready to get under-way.

In these few hours a good engineer will avail himself of the opportunity of making such temporary repairs and adjustments as are necessary, and there is always something to do when an engine is stopped.

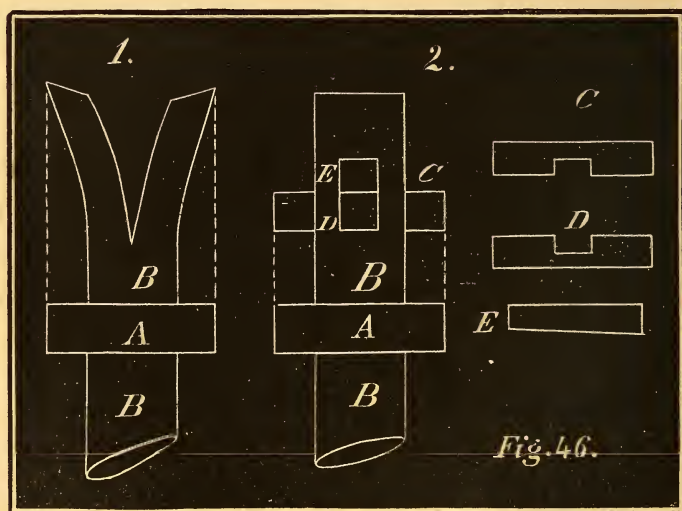
Should it be decided that the ship is to remain in port for several days, as soon as she is properly secured, and the engines are no longer needed, the sea-cocks and outboard delivery valves should be closed, fires hauled, and the water blown out of the boilers down to the crown sheets. After the boiler is cool, the remaining water can be pumped out by the hand pump, or run into the bilge. (It is confidently asserted that a large proportion of the ills that boilers are heir to are caused by a too rapid combustion in raising steam, and by blowing the water down so low that an unequal contraction takes place in the iron. That boilers generally give out first in the water bottoms and steam chimneys is doubtless the result of these two circumstances.) As soon as fires are hauled, the work of cleaning the engines should commence. The wicks should be removed from all the oil cups, the oil emptied out, and the cups thoroughly cleaned inside. The covers should then be put on, and if there are still any

openings where dirt may get upon the journals, they should be stopped up with waste or tallow. All the white lead should be removed from the bright work, and all the dirt and grease around the engines cleaned off. Potash is frequently used for this purpose, being dissolved in warm water, and applied with a mop. It is then washed off with cold water, and the work only needs to be dried, for all the white lead and grease will be removed. After the engines are cleaned, if the boilers are cool, the flues or tubes and connections should be swept, the ash pits and furnaces cleaned out, and all the dirt sent up. The bilge should also be thoroughly cleaned and whitewashed.

After the whole engine department has been properly cleaned, the men should be divided into gangs to repair and scale the boilers and overhaul the engines. And here the advantage of system is at once apparent. The engineer is not expected to work, but only to find brains for those who do. And it is astonishing how much more work some engineers can get done in a given time than others. The one who thinks of what he will need when he raises his cylinder covers, for instance, and has the falls, slings, blocks, wire for the nuts, and the like, at hand, will certainly get along faster than if he had to wait for a sling, to get a saw to cut the blocks the proper length, etc. But this is a thing that every engineer must learn for himself.

Let us first superintend the gang of men that are

working around the boilers. To scale a boiler is not the work of a few hours, as some have represented it, but, particularly in the case of tubular boilers, is a long and tedious operation, sometimes requiring two or three weeks. The crown sheets and flat surfaces can be scaled by means of hammers ground to an edge at each end. Parts not readily accessible can sometimes be scaled by means of long scaling bars, sharpened at the ends. The tubes, however, cannot be scaled in this way. In a vertical water-tube boiler we must ream the scale out of the tubes with suitable tools, and if the scale is over $\frac{1}{16}$ of an inch in thickness, two men can rarely scale more than thirty or forty tubes per day. Fig. 46 shows



two styles of tools for vertical tubes, both of which work very well.

In the first tool the collar A, on the rod, is made about $\frac{1}{16}$ of an inch less in diameter than the inside diameter of the tube. Just above the collar the rod is split, and the two pieces are bent to a width equal to the diameter of the collar. These two halves of the rod form the cutters, and are made perfectly rigid. The second tool has two cutters, C and D, at right angles to each other, and with a length equal to the diameter of the collar. The cutters have rectangular faces, and by being locked into each other are both on the same level in the rod. They are held in place by the key E.

In a horizontal, tubular boiler it is impossible to scale the tubes effectually, and all such plans as burning a train of shavings and the like are more visionary than real. All that we can do is to knock off as much as possible by means of chisel bars, and by passing flat bars of iron or steel between the tubes, and tapping them lightly. When time will permit, in scaling these boilers, it is a good plan to leave the water in the boilers, and only let it run down below the row of tubes that are to be scaled, for the scale will be much softer than if the atmosphere comes in contact with it.

While the boilers are being scaled, the other necessary repairs should be going on. The check and blow valves should be examined, scraped if necessary, and their stems repacked. All plug-cocks should also be overhauled, and made tight by scraping, if possible; if not, by grinding with a little emery

or ground glass. Before the plugs are put in again, they should be rubbed with black lead and tallow. The safety and stop valves should also be examined, and made to work freely.

Should the boilers require patching, a hard patch is preferable, if the leak is in the fire surface, otherwise a soft patch will answer. A hard patch is made by cutting out the defective iron and riveting on a patch, which can be chipped and caulked. Where it is impossible to hold the rivets for a hard patch, what is called a locomotive patch may be substituted. Here tap-bolts with heads like those of countersunk rivets, and a square shoulder to screw them into place, are used. The holes in the patch are countersunk, and the bolts are tapped into the boiler, the square shoulder being twisted off. The patch can then be chipped and caulked like a hard patch. The defective part is first cut away before putting on this patch.

The seams of some boilers, instead of being chipped and caulked, are split-caulked. But this is a cheap mode of construction, and should not be resorted to.

When there are no facilities for putting on a hard patch, or time will not permit, we must substitute a soft patch. In this case we do not cut out the defective part of the iron, but, after taking a piece of sheet lead and making a template, we turn a patch by it, putting a lip all around the edges to hold cement. The holes for the bolts are generally first cut or drilled in the boiler, and their position is

transferred to the patch by a stick with white lead on the end, which we put through the holes in the boiler, and press against the patch. When all the holes are made, the patch should be bolted to its place, and accurately fitted. It should then be taken off, a quantity of cement put on the inside, and be put on again to stay. The cement is composed of red and white lead, and fine iron borings, made as stiff as possible. Grummets, made of wicking covered with cement, should be put under the heads of the bolts, also washers under the nuts. Sometimes it is a difficult matter to get the bolts through the holes, when a method called wiring or fishing them must be resorted to. A wire is run through the hole which we wish the bolt to enter, until it can be conveniently reached, the bolt already grummeted is attached to it, and can be drawn into its proper place. Sometimes a slender rod, split at one end, which grips the bolt, is employed.

A soft patch on a fire surface should not be made of iron more than $\frac{3}{16}$ of an inch in thickness. If the leak is not a very large one, it is well to cut some holes, so as to let the water in the boiler have free access to the patch. When so fitted, a soft patch in a furnace will frequently last for several months.

A short crack in the iron of the boiler may frequently be made tight by driving rivets along it, and caulking the heads well.

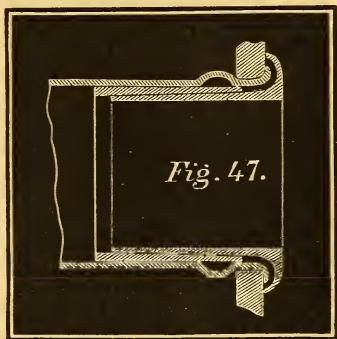
While in port, tubes that have been plugged up

should be cut out, and new ones inserted. The leaking tube is first cut clear of the tube sheets, and a long bolt is introduced into it, with a washer at one end, that will just go through the hole in the tube sheet. The other end of the bolt passes through a crowfoot resting against the other tube sheet, and, by screwing up the nut on this end of the bolt, the tube is drawn clear of one tube sheet. It can then be readily worked out the rest of the way, unless there is a very thick scale on it, when the operation is somewhat tedious. After the old tube is removed, the holes in the tube sheets should be filed smooth, if there are any irregularities in them. The new tube should not project more than $\frac{1}{8}$ of an inch beyond each tube sheet before it is expanded. Being put into its place, one end of the tube is hammered over, and the expanding tool is driven in. The same operation is then repeated at the other end. In the case of horizontal tubes, one expanding tool will answer for both ends. But vertical tubes require two, a top tool and a bottom one. In expanding the lower end of a vertical tube, one man enters the boiler underneath the lower tube sheet, and holds the expanding tool in its place, while another man drives the mandril (which passes through the tube) from the upper tube sheet.

Sometimes old tubes that leak at the tube sheets can be made tight by being caulked or re-expanded. For caulking the ends of the tubes a boot tool (so called from its resemblance to a high-heeled boot) is

often used, but a small, round-faced hammer will answer every purpose. If neither caulking nor expanding will make a tube tight, a ferule or thimble may often be driven in with very good effect. Fig. 47 is a sketch of Clark's patent thimble, which is very highly spoken of.

The ferule, it will be seen, is in two pieces. The inner piece is usually coated with red lead putty, and when the outer piece is driven up, the tube is expanded, and the leak stopped.



In overhauling the boilers, all the braces and pins should be examined. When any pins are found to be loose by corrosion, they should be removed, and larger ones put in. All the braces should be sounded with a hammer, and those that are loose upset, and made of the proper length, so as to take their share of the strain.

The bottoms of the boilers should be painted, and for this purpose the following is a most excellent preparation :

Red Lead,	50 pounds.
Venetian Red,	12 “
Whiting,	5 “
Litharge,	2½ “

Grind the ingredients in a paint mill, with boiled linseed oil. Then mix the preparation with boiled linseed oil to proper consistency for painting.

In putting on the hand and manhole plates, great care is often necessary, particularly in the case of old boilers. The iron around the hole is often corroded by the use of rubber gaskets, as they contain a large quantity of sulphur and zinc, which accounts for their action. By covering rubber gaskets with black lead and tallow, every time the plates are put on, injury to the iron may be, in a great measure, prevented. Where we cannot make a plate tight by employing a rubber gasket, a gasket of hemp packing, saturated with tallow, will frequently have the desired effect.

While the work of overhauling the boilers is progressing, the examination and repair of the engines should be going on. The cylinders and pistons should be looked at, to see if they are in good condition, if the rings fit closely to the cylinders, and if the springs require setting up. The pistons should have all the dirt removed from the inside before the followers are replaced. The foot and delivery valves should be examined, also the air-pump plungers or buckets, which should be repacked, if they require it. All stuffing boxes that leak should be repacked, and all leaky joints made anew. Where the keys of a bearing are driven home, a liner should be put behind one of the brasses, the butt or crown brass, as the case may be.

If any of the bearings have given trouble by heating, they should be examined, and the brasses scored. But large bearings that have given no trouble should not be touched, for it is a correct principle in engineering, to "Let well enough alone."

If any apprehensions are entertained that the shaft is out of line, this can be determined approximately, in the case of a direct-acting propeller engine, by disconnecting the rod at the crank-pin end, swinging it on the centres and half centres, and measuring its distance at each of these points from the crank, which we also swing around with the rod. The accurate method is to put two straight edges on the slides, one at each end; run a line through their centre points, and continue it beyond the shaft. Set a T square on one of the straight edges, making one edge of the blade cut the centre point. Then erect a perpendicular to the line we have run, at the centre of the shaft, by looking it out of wind with the edge of the T square. The distances of the crank, at the centres and half centres, from this perpendicular and athwartship line are then to be measured, and if they vary, the shaft is not in line. In the case of a side-wheel steamer, to see whether the shafts are in line with each other, we have only to measure the distances between the cranks at the centres and half centres.

In packing a large stuffing-box, such as that of a slip joint on a steam or exhaust pipe, it is well to put a piece of lead pipe, with a strand of hemp packing

run through it, in the bottom of the recess. The packing for a slip joint should be well saturated with black lead and tallow, otherwise it sometimes becomes a very difficult matter to remove the gland when repacking is necessary. In fact, black lead and tallow, or black lead alone, should be put on the faces of all joints, all cocks and rubbing surfaces, follower bolts, and the like, to prevent corrosion.

All pipes that have burst, or have holes in them, and have been wrapped temporarily, should be repaired in a more permanent manner while in port. If hard solder is to be used, the pipe is secured together by copper wire, or a patch fitted and wired in its place, the surfaces that we design to solder having previously been scraped clean. Then apply spelter solder and pulverized borax, mixed with water. Place the pipe in a charcoal or anthracite fire in the portable forge, and when the solder melts, the operation is completed. Care should be taken not to burn the pipe.

If soft solder is to be used, the pipe should first be scraped clean. Then apply a mixture of muriatic acid and water (one gill of acid to one and a half of water), in which a little zinc has been dissolved. (In the absence of the acid, pulverized rosin may be substituted.) Then run the solder into the seam with a soldering iron, previously tinned. Lamps, oil cans, and tinware can be soft soldered in the same way.

INDEX.

A.

	PAGE
Action of the Slide Valve.....	108
Air.....	63
Allen and Wells's Cut-off.....	91
Analysis of Coal.....	63
Analysis of Sea Water.....	123
Angle of the Screw	39
Areas of Chimneys.....	66
Area of the Screw's Disc.....	43

B.

Back-acting Engines.....	12
Back Pressure.....	85
Balanced Slide Valve.....	117
Banking Fires.....	161
Best Form of Propeller.....	41
Bilge Water Gauge.....	19
Blowing Off.....	129
Box Valve.....	119
Bristol's Valve.....	119
Broken Condenser and Channel Way.....	160
Burstcd Feed Pipes.....	153-172
Burstcd Tubes	167

C.

	PAGE
Cam Cut-off.....	88
Carbonic Acid	64
Carbonic Oxide.....	64
Centre of Pressure.. ..	26
Clark's Thimble.....	169
Cleaning Boilers	163
Cleaning Engines and Bilges.....	162
Cleaning Fires	149
Combustion.....	63
Comparison of Pitches of Propellers	41
Comparison of Feathering and Radial Wheels.....	21
Condensers.....	132
Cornish Valve	117
Counter	19
Cracked Cylinder.....	158

D.

Davies's Valve	122
Definition of Steam	73
Definition of Screw Propeller	37
Derangement of Feed Pumps.....	155
Description of the Indicator.....	95
Dickerson's Boiler	16
Direct-acting Engines	11
Double Puppet Valves.....	117
Draft	66
Drag	35
Duties of an Engineer.....	145
Duties to Boilers.....	148
Duties to Engines.....	154

E.

Efficiency of Boilers.....	105
Engineers' Note Book.....	157
Equilibrium Oil Cup.....	21
Erection of Engines	69

	PAGE
Examining Bearings.....	170
Example in Expansion.....	78
Expanding Pitch.....	39
Expansion Diagram.....	100
Expansion of Steam.....	75

F.

Feathering Wheel.....	22
Filling the Boilers.....	146
Firing.....	149
Flue Boiler.....	14
Foaming.....	151
Fogle's Oil Cup.....	21
Friction of an Engine.....	104
Friction of Feathering Mechanism.....	36

G.

Gain by use of Heaters.....	134
Gain in Fuel by Expansion.....	81
Gain in Mechanical Effect by Expansion.....	77
Geared Engines.....	12
Generatrix of Propeller.....	37
Geometrical Action of the Slide Valve.....	110
Green's Cut-off.....	93

H.

Hauling Fires.....	162
Haystack Boiler.....	15
Helicoidal Area.....	57
High Pressure Diagram.....	102
Horizontal Tubular Boiler.....	14
Horse-power of a Boiler.....	105
Horse-power of an Engine.....	102
How to draw the Curve of Expansion.....	78
How to lay down a Propeller.....	47
How to measure a Propeller.....	45
How to sweep up a Propeller.....	56

I.

	PAGE
Injection Water required.....	138
Impaired Vacuum.....	156

J.

Joints of Engines.....	72
------------------------	----

L.

Lap.....	110
Latent Heat of Steam.....	74
Lead.....	110
Leaks in Boilers.....	153
Lighthall's Refrigerator.....	137
Limit to Expansion.....	85
Limit to Lap.....	114
Lining Holes through Ship's Side.....	72
Lining up the Shaft.....	171
Link Motion.....	94
Long's Salinometer Pot.....	128
Loss by Blowing.....	133
Loss by Oblique Action.....	30
Low Water.....	152

M.

Man and Hand-hole Plates.....	170
Manley Wheel.....	22
Material for Propellers.....	57
Mean Pressure during Expansion.....	77
Mechanical Effect of Expansion.....	77
Miscellaneous Repairs to Boilers.....	165

N.

Negative Slip.....	43
New Ironsides' Valve.....	122
Number of Blades of Propeller.....	43

O.

PAGE

Objection to Feathering Wheels	25
Oscillating Engines	12
Overhauling Braces.....	169
Overhauling Engines.....	170

P.

Packing large Stuffing-boxes.....	171
Paint for Boilers.....	169
Patching Boilers.....	166
Percussion Gauge.....	18
Pirrson's Condenser.....	135
Pitch of Propeller.....	38
Piston Valve	120
Porter's Indicator	95
Properties of Steam	73
Putting in Tubes	167

Q.

Quantity of Water blown off.....	129
----------------------------------	-----

R.

Radial Wheel.....	21
Raising Steam.....	147
Relations of Power and Speed	141
Repairing leaking Tubes	168
Repairing Pipes.....	172
Resistance to a Ship's motion.....	140
Rolling Circle.....	25
Root's Engine.....	13
Rotary Engines	12
Rotary Valve.....	120

S.

Salinometer.....	125
Salt in Tube Boxes	157

	PAGE
Scale	124
Scale Preventives	130
Scaling Boilers.....	163
Scaling Tools	164
Setting Boilers	71
Setting Slide Valves.....	114
Sewell's Condenser	136
Sickel's Cut-off.....	90
Side Lever Engine.....	11
Slide Cut-offs.....	92
Slip of Paddle-wheels.....	33
Slip of Propeller.....	42
Speed of large and small Vessels.....	143
Steam and Vacuum Gauges	17
Steaming against a Current.....	143
Stephens's Cut-off.....	90
Stimer's Boiler.....	17
Sweeping Flues under way.....	157
System in Overhauling	163

T.

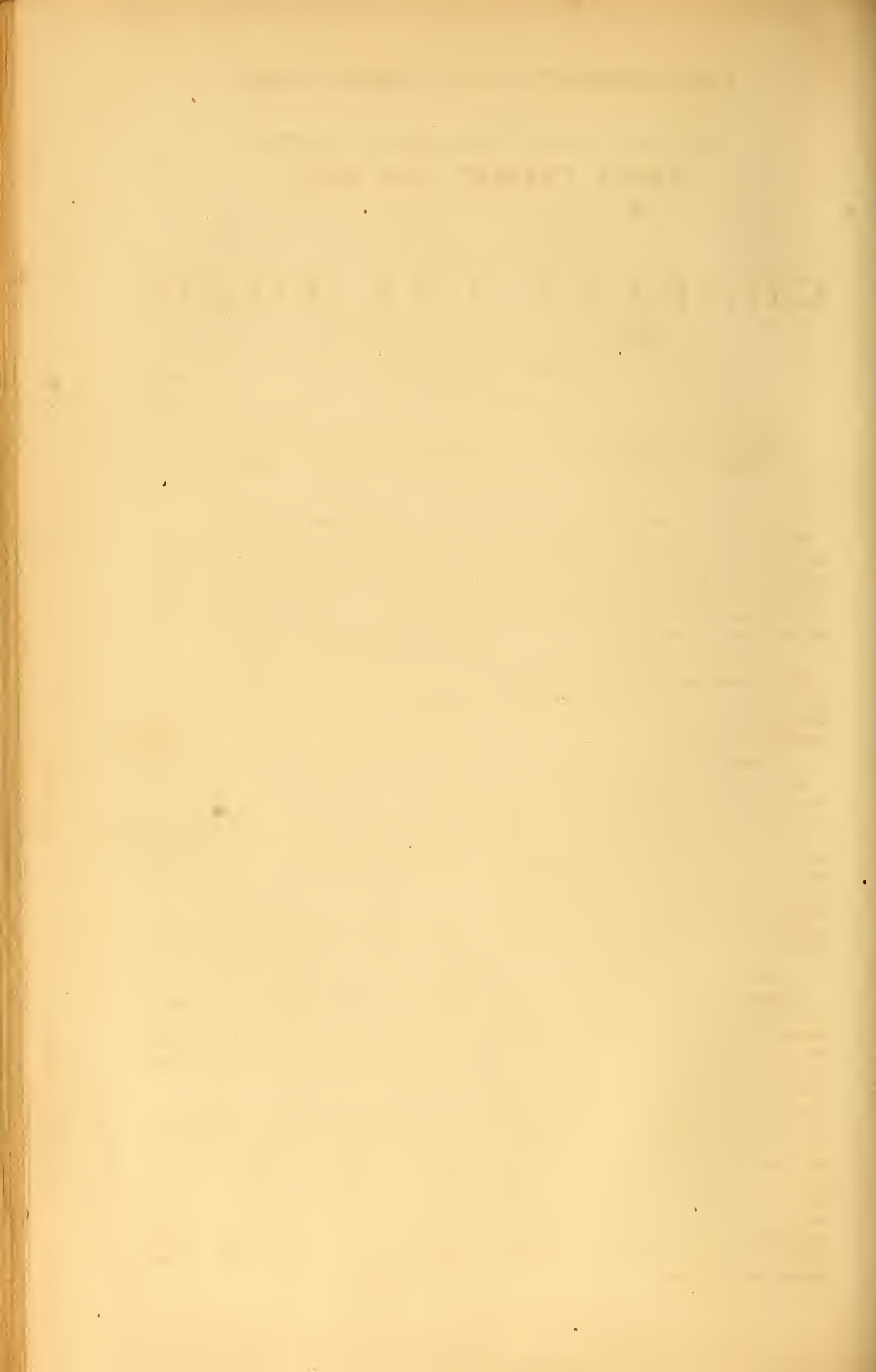
Table of Atomic Weights and Volumes.....	67
Table of Hyperbolic Logarithms.....	78
Table of Initial Pressure.....	84
Table of the Properties of Steam	75
Taking a Diagram.....	97
Terminal Pressure of Expanded Steam	77
Theoretical Curve of Expansion.....	76
Theoretical Diagram, and Practical Modification.....	98
Thermometer used as a Salinometer.....	127
Thrust of Propeller.....	44
Trunk Engines	12

V.

Vertical Tubular Boiler	14
-------------------------------	----

W.

	PAGE
Waddell's Valve.....	121
Warming the Engines.....	147
Water as Fuel.....	65
White Leading Bright Work.....	147
Winter's Cut-off.....	92
Wooding Furnaces	146
Wright's Engine	13



"The most striking literary product of the year."

KIRK'S CHARLES THE BOLD.

**HISTORY OF
CHARLES THE BOLD,
DUKE OF BURGUNDY.**

BY JOHN FOSTER KIRK.

2 Vols. 8vo.

Muslin, uncut, on white paper..... \$3 00 per vol.
Half Morocco, with Vellum Cloth Sides and Gilt Top, on
Tinted Laid paper..... 3 50 "

From the ATLANTIC MONTHLY.

We have no hesitation in assigning to Mr. Kirk's most fascinating narrative a place with the great achievements of genius in the department he has chosen to fill. His advent among historians will be welcomed the world over.

From the NEW YORK TRIBUNE.

Will unquestionably establish the title of Mr. Kirk to an eminent position in the already justly honored school of American historians.

From the CHRISTIAN EXAMINER.

Mr. Kirk has been very fortunate in the choice of a subject for his first great historical work, and if the concluding volume shall be executed with the same ample learning, the same thorough mastery of his subject, and the same fidelity of purpose which are exhibited in the volumes now published, few persons will question his right to a place among the best of our living historians. * * *

From the EVANGELICAL QUARTERLY.

Nothing within the compass of modern literature has been published more attractive than the narrative contained in the volumes before us. It is one of absorbing interest. The author always rises to the measure of his subject, and, placing himself in genial sympathy with his characters, inspires his readers with something of the same enthusiasm. The style is simple yet rich, the narrative bold and striking; the facts are presented with great discrimination and skill. The work is an honor to the accomplished author, who is destined to take a prominent position among our American historians.

From the NEW YORK TIMES.

Nothing can be more certain than that Mr. Kirk has enriched the literature of America and Europe with a work that takes at once its destined stand in our libraries and in the estimation of competent judges and the public. * * * His success places the author in a proud position, and we look forward to meeting him again, possibly in subjects more congenial to his great powers of reasoning and political disquisition. With the exception of a few spots illuminated by the genius of Prescott and Motley, the modern history of Continental Europe for the two centuries previous to the French Revolution is almost a blank to the American reader, and needs for its illustration the qualities that Mr. Kirk so largely possesses.

From the BOSTON TRANSCRIPT.

This work will more than answer the highly raised expectations of the public, both in respect to the author's extent of original research and novelty of matter, while in fluency and picturesqueness of narrative style, and thorough grasp of the subject in all its details, it will take a proud place among the most esteemed histories of the country.

From the PHILADELPHIA INQUIRER.

The most striking literary product of the year, and one that will be a standard while English speech endures, is Mr. Kirk's HISTORY OF CHARLES THE BOLD. In delineation of character it is admirable; in research thorough, exhaustive, systematic; in style charming without profuse ornament, logical and precise without being dry. * * *

Boswell's Life of Johnson.

First complete American edition, including a Journal of his Tour to the Hebrides
With numerous additions, by JOHN WILSON CROKER, M.P., and Notes by various hands. 4 vols. 12mo.

The Works of Lord Chesterfield.

Comprising his Letters to his Son. Complete. 1 vol. 12mo.

The Works of Hannah More.

Comprising "Coelebs in Search of a Wife," "Shepherd of Salisbury Plains,"
"Tales and Allegories," etc., with a portrait on steel. 2 vols. 12mo.

Hume's History of England.

The History of England, from the Invasion of Julius Cæsar to the Abdication of James II., 1688. By DAVID HUME, Esq. A new edition, with the author's last corrections and improvements; to which is prefixed a short account of his life, written by himself. 6 vols., with portrait.

Gibbon's Decline and Fall of the Roman Empire.

The History of the Decline and Fall of the Roman Empire. By EDWARD GIBBON, Esq. With Notes by Rev. H. H. Milman. A new edition; to which is added a complete Index of the whole work. 6 vols., with portrait.

Macaulay's History of England.

The History of England, from the Accession of James II. By THOMAS BABINGTON MACAULAY. In 5 vols. 12mo edition, complete. With Portrait and full Index.

This edition is in all respects the most valuable and satisfactory of any published in this country or in England, inasmuch as the fifth volume, in addition to a full and well-classified index, contains a biographical and critical sketch of Macaulay's life, character, and writings, by S. Austin Allibone, whose eminent fitness for this work will be uni-

versally admitted. Mr. Allibone's biographies and criticisms upon his writings down to 1857 were submitted to Mr. Macaulay, whose personal revision thus renders the article accurate and therefore perfectly reliable. The fifth volume also contains a double-page facsimile from one of Mr. Macaulay's latest MSS.

Goldsmith's Complete Works.

Embracing numerous pieces, now first collected, with copious Notes, by JAMES PRIOR. With four Vignettes engraved on steel. 4 vols. 12mo.

Jefferson's Writings.

The writings of Thomas Jefferson. Being his Autobiography, Correspondence, Reports, Messages, Addresses, and other Writings, Official and Private. Published by the order of the Joint Committee of Congress on the Library, from the Original Manuscripts deposited in the Department of State. With Explanatory Notes, Tables of Contents, and a copious Index to each volume, as well as a General Index to the whole. By the Editor, H. A. WASHINGTON. 9 vols. 8vo.

J. B. LIPPINCOTT & Co.'s PUBLICATIONS.

CHAMBERS'S BOOK OF DAYS.

THE BOOK OF DAYS:

A Miscellany of Popular Antiquities in connection with the Calendar, including Anecdote, Biography, and History, Curiosities of Literature, and Oddities of Human Life and Character. Edited under the supervision of ROBERT CHAMBERS. In two volumes, Royal 8vo.

This interesting work consists of—

- I. Matters connected with the Church Calendar, including the Popular Festivals, Saints' Days, and other Holidays, with illustrations of Christian Antiquities in general.
- II. Phenomena connected with the Seasonal Changes.
- III. Folk-Lore of the United Kingdom, namely, Popular Notions and Observances connected with Times and Seasons.
- IV. Notable Events, Biographies, and Anecdotes connected with the Days of the Year.
- V. Articles of Popular Archaeology, of an entertaining character, tending to illustrate the progress of Civilization, Manners, Literature, and Ideas.
- VI. Curious Fugitive and Inedited Pieces.

From the BOSTON TRANSCRIPT.

A book occasionally appears which is precisely adapted to the wants of those for whom it is intended. The "Book of Days" is the best representative of this class. Designed to instruct and amuse the home circle, containing matter of the most varied sort and of general interest, prepared and arranged

with ability and care, handsomely, profusely, and appropriately illustrated, it cannot fail to find its way to every reading family, and must become immensely popular. * * * It is, however, next to impossible to describe this work; if our readers see it they will buy it, especially if they want a book for the fireside.

PRESCOTT'S WORKS.

New Crown Octavo Edition.

Conquest of Mexico. History of the Conquest of Mexico, with a preliminary view of the ancient Mexican civilization, and the life of Hernando Cortez. By WM. H. PRESCOTT. Three vols.

Conquest of Peru. History of the Conquest of Peru, with a preliminary view of the civilization of the Incas. By WM. H. PRESCOTT. Two vols.

Ferdinand and Isabella. History of the Reign of Ferdinand and Isabella the Catholic. By WM. H. PRESCOTT. Three vols.

Philip the Second. History of the Reign of Philip the Second, King of Spain. By WM. H. PRESCOTT. Three vols.

Charles the Fifth. History of the Reign of the Emperor Charles the Fifth. By WM. ROBERTSON, D.D. With an account of the Emperor's life after his abdication. By WM. H. PRESCOTT. Three vols.

Prescott's Miscellanies. Biographical and Critical Miscellanies. By WM. H. PRESCOTT. One vol.

PRESCOTT'S COMPLETE WORKS.

Uniform in 15 vols., in various styles of binding.

J. B. LIPPINCOTT & Co.'s PUBLICATIONS.

Baird's Mammals.

Mammals of North America: The descriptions of species based chiefly on the collections in the Museum of the Smithsonian Institution. By SPENCER F. BAIRD, Assistant Secretary of the Smithsonian Institution. One vol. 4to., of 854 pp with 32 wood-cuts and 87 plates of figures illustrating the genera and species. Colored plates, \$15.00. Plain plates, \$10.00.

Bulwer's Works.

The Works of Sir Edward Bulwer Lytton, Bart., D.C.L. Uniform library edition, in forty-two vols. 12mo., elegantly printed on tinted paper and bound in cloth, sheep and half calf.

THE CAXTON NOVELS.

The Caxton Family	2 vols.
My Novel	4 vols.
What will he do with it?	3 vols.

HISTORICAL ROMANCES.

Devereux	2 vols.
The Last Days of Pompeii	2 vols.
Rienzi	2 vols.
The Siege of Granada	1 vol.
The Last of the Barons	2 vols.
Harold	2 vols.

ROMANCES.

Pilgrims of the Rhine	1 vol.
Eugene Aram	2 vols.
Zanoni	2 vols.

NOVELS OF LIFE AND MANNERS.

Pelham	2 vols.
The Disowned	2 vols.
Paul Clifford	2 vols.
Godolphin	1 vol.
Ernest Maltravers—First Part	2 vols.
Ernest Maltravers—Second Part, (Alice)	2 vols.
Night and Morning	2 vols.
Lucretia	2 vols.
A Strange Story	2 vols.

 Each work furnished separately if desired.

Parables of our Lord.

Beautifully printed in Ornate Saxon type on tinted paper, and magnificently Illustrated with Engravings on Steel. Folio.

New Dictionary of Quotations.

A New Dictionary of Quotations, from the Greek, Latin, and Modern Languages, translated into English, and occasionally accompanied with Illustrations, Historical, Poetical, and Anecdotal. With an extensive Index, referring to every important word. One vol. crown 8vo., muslin, beveled boards.

On the score of utility it may be classed among the most excellent and convenient, not only to the general reader, but to the scholar who, in ac-

tive life, has suffered his classics to rust. The New Dictionary will find a place in the hands of every reader of current literature.—*North American*.

Lieber's Civil Liberty.

On Civil Liberty and Self-Government. By FRANCIS LIEBER, LL.D., author of "Political Ethics," "Principles of Legal and Political Interpretation," etc. etc. 8vo.

 This work is used as a text-book in our best institutions of learning.

It is to all intents and purposes a text-book of American politics. Would that it might be generally regarded as such! Then our young men, instead of wasting too much time upon ephemeral reading, would be laying up a store of com-

prehensive facts and principles which would prove of enduring value to themselves and the country; they would see in what true liberty consists, and would recognize the sure means of its perpetuation.—*Boston Journal*.

Parsons on Notes and Bills.

A Treatise on the Law of Promissory Notes and Bills of Exchange, with an Appendix, containing an accurate reprint of the Provisions of the Statute in relation to Bills, Notes, Letters of Credit, Drafts, Orders, and Checks; together with an examination of the questions which the Statute suggests, and the English authorities upon those questions which have arisen under the English Stamp Acts, and may arise under our own. By THEOPHILUS PARSONS, LL.D., Professor of Law in Cambridge University. Two vols. 8vo.

* * * The general character of the Treatise is exhaustiveness, the learned author having labored with splendid success to make his work one that shall meet all the requirements of that province of Law to which it is devoted, and

to give to persons interested therein a guide upon which the completest reliance can be placed. Its publication adds to his high fame, and it places the entire business world under the greatest obligations to him.—*Boston Traveller*.

Hilliard on Bankruptcy and Insolvency.

A Treatise on the Law of Bankruptcy and Insolvency. By FRANCIS HILLIARD, author of "The Law of Torts," etc. One vol. 8vo.

Mr. Hilliard's book is evidently the result of much intelligent labor, and, as a complete, methodical, and well digested summary of the present law, will be of great value to the profession, espe-

cially since the recent vote of the House of Representatives appears, for the present at least, to have settled the question of a new and permanent national law of bankruptcy.—*American Law Register*.

Johnson's Lives of the English Poets.

With Critical Observations on their works. With Notes, by PETER CUNNINGHAM, and a Life of the Author, by MACAULAY. With a portrait on steel. Two vols. 12mo.

Hamilton's History of the United States.

History of the Republic of the United States of America as traced in the writings of Alexander Hamilton and of his cotemporaries. By JOHN C. HAMILTON. In seven vols. 8vo. (Vol. VII. just published.)

The Federalist.

A Commentary on the Constitution of the United States; a collection of Essays by Alexander Hamilton, Jay, and Madison; also the Continentalist and other papers, by Hamilton. Edited by JOHN C. HAMILTON, author of the "History of the Republic of the United States." In one vol. 8vo.

Sloan's Architectural Works.

Sloan's Constructive Architecture : A guide for the builder and carpenter; exhibiting the construction of a series of designs for roofs, domes, spires, and the five orders of architecture, selected from the best specimens of Grecian and Roman art, with the figured dimensions of their height, projection, and profile. To which is added a treatise on practical geometry. The whole illustrated by 62 plates, and accompanied by explanatory text. By SAMUEL SLOAN, Architect, author of the "Model Architect," "City and Suburban Architecture," etc. etc. One vol. 4to.

Sloan's City and Suburban Architecture : In which are exhibited numerous designs and details for public edifices, private residences, and mercantile buildings. Illustrated with 136 folio engravings, accompanied by specifications, and historical and explanatory text. By SAMUEL SLOAN, author of the "Model Architect," "Sloan's Constructive Architecture," etc. etc. One vol. folio.

Sloan's Homestead Architecture : Containing forty designs for villas, cottages, and farm-houses, with essays on style, construction, landscape gardening, furniture, etc. Illustrated with upwards of 200 engravings. By SAMUEL SLOAN, Architect. One vol. 8vo.

The first of these works is adapted to the wants of the practical builder and mechanic, presenting in natural succession numerous examples of forms generally esteemed the most useful in constructive carpentry. The second is devoted mainly to city architecture, containing a great number of designs and illustrations for public edifices, private residences, and mercantile buildings. Each volume is illustrated by a great variety of elegant engravings, and besides the value of the reading matter, which to a great extent is founded on the personal experience of the author, in point of typographical finish and beauty is a model of tasteful and attractive execution.—*N. Y. Tribune.*

Sloan's Constructive Architecture is one of the very best and most elegant books on architecture that has appeared from the American press. It is prepared in the clearest manner, and beautifully

illustrated, and will be found of great value not only to architects, but to builders of all classes. The plates which illustrate and explain the text are drawn with rare skill, and are superb specimens of engraving.—*Evening Transcript.*

Sloan's Constructive Architecture is a full and eminently practical treatise on the higher branches of carpentry, joinery, and building, and is such a work as every builder who is not a mere imitator of the plans of others will desire to possess.—*Boston Journal.*

City and Suburban Architecture is a perfect storehouse of knowledge on all subjects and details which relate to the subject of architecture. * * * It will serve the student as well as the master, for it furnishes an abundance of information as to the early progress of architecture, and the rapid stride of improvement in modern times.—*Boston Post.*

Chauvenet's Astronomy.

A Manual of Spherical and Practical Astronomy, embracing the General Problem of Spherical Astronomy, its special applications to Nautical Astronomy, and the Theory and Use of Fixed and Portable Astronomical Instruments. With an Appendix on the "Method of Least Squares." Illustrated by engravings on wood and steel. By WILLIAM CHAUVENET, Professor of Mathematics and Astronomy in Washington University, St. Louis. 2 vols. Royal 8vo. \$10.00.

Army of the Cumberland.

Annals of the Army of the Cumberland, comprising Biographies, Descriptions of Departments, Accounts of Expeditions, Skirmishes, and Battles; also its Police Record of Spies, Smugglers, and Prominent Rebel Emissaries, together with Anecdotes, Incidents, Reminiscences, etc., and Official Reports of the Battle of Stone River. By an OFFICER. Illustrated with numerous Steel Portraits, Engravings, and Maps. 8vo.

Marks's Peninsular Campaign.

The Peninsular Campaign in Virginia; or, Incidents and Scenes on the Battle Fields and in Richmond. Illustrated with numerous engravings. By Rev. J. J. MARKS, D.D., Chaplain of the 63d Pennsylvania Regiment. 12mo. \$1.50.

Cassin's American Ornithology.

American Ornithology; giving a General Synopsis of North American Ornithology, and containing Descriptions and Figures of all North American Birds not given by former American Authors, after the manner, and designed as a continuation of the Works of Audubon. By JOHN CASSIN, Member of the Academy of Natural Sciences of Philadelphia, etc. etc. Illustrated with fifty beautifully-colored Plates. One vol. 8vo.

Cassin's Mammalogy and Ornithology.

The Mammalogy and Ornithology of the United States Exploring Expedition, under the command of Commodore Wilkes. Prepared under the superintendence of JOHN CASSIN, Member of the Academy of Natural Sciences, etc. One vol. quarto, with a Folio Atlas of over fifty colored Engravings. \$50.00.

 Only 150 copies of this work published.

Baird's Birds of North America.

The Birds of North America: The descriptions of species based chiefly on the collections in the Museum of the Smithsonian Institution. By SPENCER F. BAIRD, Assistant Secretary of the Smithsonian Institution; with the co-operation of JOHN CASSIN, of the Academy of Natural Sciences of Philadelphia, and GEO. N. LAWRENCE, of the Lyceum of Natural History of New York. With an Atlas of one hundred plates. Text, one vol. 4to., \$5.00; Atlas, one vol. 4to., \$15.00.

Randall's Life of Jefferson.

The Life of Thomas Jefferson. By HENRY S. RANDALL, LL.D. In 3 vols. 8vo.

Illustrated by Portraits and other Engravings on Steel, a View of Monticello, and various fac-similes, including the Original Draft of the Declaration of Independence.

This Life of Mr. Jefferson is, in every sense, an authorized work. It was undertaken under the approbation of his family, with an unreserved access to and use of all the private papers of Mr. Jefferson in their possession, and has received the benefit of their recollections and opinions at every step. The purely original matter comprises about one-third of the work. In the department of the biography, embracing some materials which have already been pub-

lished, it has been Mr. Randall's aim, as often as practicable, to present Mr. Jefferson's own words. The work contains his expressions on perhaps every great question which arose from his advent in public life to his death,—a period of about sixty years, and embracing the whole FORMING period of the Republic. The work contains, besides Mr. Jefferson's heretofore unpublished family correspondence, selections from his finest published letters, state papers, etc.

Carey's Social Science.

The Principles of Social Science. By HENRY C. CAREY, LL.D. In 3 vols. 8vo.

Of his system it may be truly said that, although the study of *political economy* dries up narrow minds and reduces their vision on earth to goods and sales and profits, *this study* must ever be, for minds nobly endowed, a source of exalted meditation upon the means of ameliorating the lot of the human family, and upon the blessings vouchsafed by

the Eternal Author of all good.—*North American*.

However the reader may sometimes join issue with the logic or recoil from the conclusions of this production, it will never be without respect for the signal ability displayed by the writer in this difficult walk of scientific literature.—*National Intelligencer*.

Great Truths by Great Authors.

A Dictionary of Aids to Reflection, Quotations of Maxims, Counsels, Cautions, Aphorisms, Proverbs, etc. etc., from Writers of all Ages and both Hemispheres. 1 vol. demi 8vo.

Thiers's Consulate and Empire of Napoleon.

The History of the Consulate and Empire of France under Napoleon. By M. ADOLPHE THIERS, late Prime Minister of France, Member of the French Academy and of the Institute. Complete in 5 vols. 8vo.

The Publishers have the pleasure of announcing that this great work of M. Thiers is completed,—the concluding volume (V.) having just been issued

uniform with the volumes preceding. Either of the volumes will be furnished separately, in any style of binding, to complete sets.

Beck's Medical Jurisprudence.

Elements of Medical Jurisprudence. By THEODRIC ROMEYN BECK, M.D., LL.D., and JOHN B. BECK, M.D. *Twelfth edition*. With Notes by an association of the friends of Drs. Beck. The whole revised by C. R. Gilman, M.D., Professor of Medical Jurisprudence in the College of Physicians and Surgeons of New York. 2 vols. 8vo.

From PROF. J. W. FOWLER, LL.D., Principal "State and National Law School," Poughkeepsie, N. Y.

* * * It should be in the possession of all who desire a ready access to this

most interesting and important branch of Legal Science, a knowledge of which is essential to professional success.

J. B. LIPPINCOTT & Co.'s PUBLICATIONS.

Scott's Waverley Novels.

In various styles, including—

I. An Abbotsford Edition.—Complete in twelve volumes, demi octavo, with illustrations.

II. A Royal Octavo Illustrated Edition.—In twelve volumes, splendidly illustrated with over 800 engravings, comprising Landscapes, Incidents, and Portraits of the Historical personages described in the Works.

III. A Pictorial Edition.—In twenty-four volumes, duodecimo, illustrated with over 800 steel and wood engravings.

IV. A People's Edition.—Complete in six volumes, octavo, illustrated.

V. A New and Beautifully Illustrated Edition.—In forty-eight volumes, cap 8vo., printed on a beautiful Long Primer Type, and illustrated with over 1500 wood-cuts and steel engravings. (Published in connection with the Messrs. A. & C. Black, of Edinburgh.)

Jomini's Art of War.

The Art of War. By BARON DE JOMINI, General and Aid-de-Camp of the Emperor of Russia. A new edition, with appendices and maps. Translated from the French by Captain G. H. MENDELL, U.S.A., Corps of Topographical Engineers, and Lieutenant W. P. CRAIGHILL, U.S.A., Corps of Engineers. One vol. demi 8vo. \$1.50.

While everybody is criticising the war, would it not be well for somebody to read this greatest of military critics, and know a mere smattering about the matters so dogmatically discussed? *

* * * It might be convenient occasionally in conversation to back up an opinion by an allusion to the Baron de Jomini. It must be confessed that *he knows something about war.*—*Con. Courant.*

Manual for Courts Martial.

A manual for Courts Martial: Containing full explanations of the duties of all officers employed on such service, and complete forms of proceedings, with an Appendix and Index. By Captain HENRY COPPÉE, late Instructor in the Military Academy at West Point. 18mo.

Chambers's Encyclopædia.

A Dictionary of Universal Knowledge for the People, on the basis of the latest edition of the German Conversations-Lexicon. Illustrated with Maps and numerous wood Engravings. Published in parts and volumes. The whole to be comprised in nine volumes, royal 8vo. Vol. VII. just published.

Steel-plate Maps, beautifully printed in colors, to illustrate the geographical portion of the Encyclopædia, are furnished to subscribers at the following prices:

The Maps for Vol. I. are seven in number, price \$.50

“ “ “ “ II. “ three “ “ .25

“ “ “ “ III. “ two “ “ .16

“ “ “ “ IV. “ three “ “ .25

“ “ “ “ V. “ six “ “ .50

“ “ “ “ VI. “ two “ “

“ “ “ “ VII. “ two “ “

Subscribers to the monthly parts will be furnished with muslin cases for the volumes at a reasonable charge, or the publishers will bind the volumes in any style that may be desired, at reasonable rates.

J. B. LIPPINCOTT & Co.'s PUBLICATIONS.

WORKS OF JAMES MADISON.

Letters and Other Writings of James Madison,

FOURTH PRESIDENT OF THE UNITED STATES.

IN FOUR VOLUMES. PRICE \$16.00.

Now First Published.

On the 31st of May, 1848, Congress passed an act appropriating \$25,000 to purchase from Mrs. Madison all the unpublished MSS. of her husband.

The works thus purchased have been embodied in the four volumes now offered to the public, which contain letters of Mr. Madison from 1769 to 1836, together with some important additions, among which are Mr. Madison's celebrated "Examination of the British Doctrine," etc., written in 1806; his pamphlet entitled "Political Observations," published 1775; some "Essays," chiefly political; the "Virginia Proceedings of 1798," etc., etc.; together with Mr. Madison's "Statements in Relation to Secretaries Smith and Armstrong;" his Apologue of "Jonathan and Mary Bull;" his "Memorandum of Bollman's Interview with President Jefferson concerning Burr's Conspiracy;" his "Letter on Napoleon's Return from Elba;" his "Note for the Princess," now Queen Victoria; and his "Advice to my Country." The whole edited under the direction of the Joint Committee on the Library of Congress.

Elliot's Debates on the Constitution.

The Debates in the Several State Conventions on the Adoption of the Federal Constitution, as recommended by the General Convention at Philadelphia, 1787. Together with the Journal of the Federal Convention, Luther Martin's Letter, Yates's Minutes, Congressional Opinions, Virginia and Kentucky Resolutions of 1798-99, and other Illustrations of the Constitution. Including the

Madison Papers, containing the Debates on the Adoption of the Federal Constitution in the Convention held at Philadelphia in 1787, with a Diary of the Debates of the Congress of the Confederation, as reported by James Madison. Published under the sanction of Congress. By JONATHAN ELLIOT. Complete in five vols. 8vo. \$15.00.

A very important work, illustrating the history of the Constitution, and exhibiting the opinions of the ablest statesmen in the country on its several provisions at the time when its adoption by the States was under consideration. The Journal of the Convention throws great light on this subject, inasmuch as it makes us acquainted with the real intentions of the framers of the Constitution, as indicated by the proceedings, from day to day, till the great work was completed. The other illustrations of the Constitution contained in these volumes are of scarcely less interest and importance.

Schoolcraft's Great National Work.

Archives of Aboriginal Knowledge, containing all the original papers laid before Congress respecting the *History, Antiquities, Language, Ethnology, Pictography, Rites, Superstitions, and Mythology* of the Indian Tribes of the United States. Numerous illustrations. 6 vols. imperial quarto.

Ritter's Comparative Geography.

Comparative Geography. By CARL RITTER, late Professor of Geography in the University of Berlin. Translated by REV. WILLIAM L. GAGE. 12mo. \$1.50.

SUMMARY OF CONTENTS.

Introduction. Introductory Remarks—The Earth as the Dwelling-place of Man—Geography as a Science—What Geographical Science has yet to accomplish—Sources of Geographical Science—The Sciences Illustrative of Geography.

Part First. THE SURFACE OF THE EARTH CONSIDERED IN ITS MOST GENERAL RELATIONS.—The Spheroidal Form of the Earth—The Threefold Covering of the Earth—The Superficial Dimensions of the Land and Water on the Globe—Contrast of the Land and Water Hemispheres—The Position of the Continents and its Influence on the Course of History—The Pyramidal Forms of the Great Land-masses and their Southward Direction toward the Oceanic Hemisphere—Situation of the Continents in their Relation to each other and to their collective whole—The Historical Element in Geographical Science.

Part Second. A MORE EXTENDED INVESTIGATION REGARDING THE EARTH'S SURFACE.—Highlands or Plateaus—Mountains and Mountain Lands—The Relations of Plateau Systems—Primeval Formation of Plateaus and Mountains—Origin of Plateaus—Origin of Mountains—Lowlands—Middle European Lowland—Origin of the Great Central European Plain—The Ponto-Caspian Plain—Origin of Ponto-Caspian Depression—Depression of the Jordan Valley and of the Dead Sea—Bitter Lakes of the Suez Isthmus—Regions of Transition between Highlands and Lowlands: the River Systems of the Globe—Terrace Lands and Rivers—Upper, Middle, and Lower Course of Rivers—Historical Influence of Plateaus—Influence of River Systems on Civilization.

Part Third. CONFIGURATION OF THE CONTINENTS.—Superficial Dimensions and Articulation of the Continents—Islands—Results of the above considerations briefly stated—The New World.

From JAMES PYLE WICKERSHAM, A.M.,
*Principal of the Pennsylvania State Normal School
at Millersville.*

I have read Ritter's "Comparative Geography," as translated by William L. Gage, with very great satisfaction. It is a comprehensive, compact, and clear statement of the great principles of geographical science. Geography, as presented in our ordinary treatises, is not at all a science, but merely a collection of facts and fragments. In this book, however, all details find their proper place in a philosophical system. No teacher of geography should be without the book.

From the CALIFORNIA TEACHER.

This volume consists of the courses of lectures by Ritter before the University of Berlin, and contains much reliable information which can be used in the school-room daily by any active teacher. Ritter was the first, we think, to show to the world that geography was a science of relations, and not a mere mass of

unorganized facts, as the relation of a country to its national life, and to the civil structure or State. He treated it as an organized unity, and made the Earth the *home* of man—the theater of soul, and mind, and character. He thought that every people was the reflection of the country which it inhabited. The Introductory Lecture is worth alone the price of the volume, as it reveals his whole plan of treatment of geography, as a prominent and distinct science, and shows how insignificant have been our ideas of it hitherto. We heartily recommend it to all teachers.

From the NEW YORK TEACHER.

Mr. Gage could not have done a better service to American students than that of giving them, in their own vernacular, this elementary treatise, by the greatest of the German geographers. This book is a complete though elementary treatise on physical geography, and will be found a valuable aid to teachers and advanced students.

J. B. LIPPINCOTT & Co.'s PUBLICATIONS.

Climatology of the United States.

Climatology of the United States, and of the Temperate Latitudes of the North American Continent; embracing a full comparison of these with the Climatology of the Temperate Latitudes of Europe and Asia; with Isothermal and Rain Charts, including a summary of Meteorological Observations in the United States, condensed from recent scientific and official publications. By LORIN BLODGET, author of several Reports on American Climatology. One vol. large octavo. \$5.00.

Scribner on Dower.

A Treatise on the Law of Dower, embracing the Common Law and the Statutory Provisions and Judicial Decisions of England and the several United States upon that subject. 2 vols. 8vo. Vol. I. \$6.00; Vol. II. in press.

The Loves and Heroines of the Poets.

By RICHARD HENRY STODDARD. Illustrated with real and ideal portraits from designs by Barry and others, in steel, of Petrarch's Laura, Tasso's Leonora, Surry's Geraldine, Jonson's Celia, Shakspeare's "Love," Waller's Sacharissa, Pope's Martha Blount, Byron's Maid of Athens, Burns's Highland Mary, Coleridge's Genevieve, Longfellow's Minnehaha, Tennyson's Maud. 1 vol. 4to.

Wood and Bache's Dispensatory.

The Dispensatory of the United States of America. By GEORGE B. WOOD, M.D., President of American Philosophical Society, etc., etc., and FRANKLIN BACHE, M.D., late Professor of Chemistry in Jefferson Medical College, etc., etc. Twelfth edition, carefully revised. 1 vol. 8vo.

"Some idea may be formed of the amount of new matter added to the Dispensatory in this revision when it is understood that, notwithstanding the very considerable space gained by the consolidation of the three British Pharmacopœias into one, and the consequent substitution, in many instances, of a

single process and its necessary commentary for three, and notwithstanding the effort made to compress everything to be said into the fewest possible words, and to leave no part of the space unoccupied, it has nevertheless been found necessary to extend the limits of the work by more than one hundred pages."

Thomas's Pronouncing Medical Dictionary.

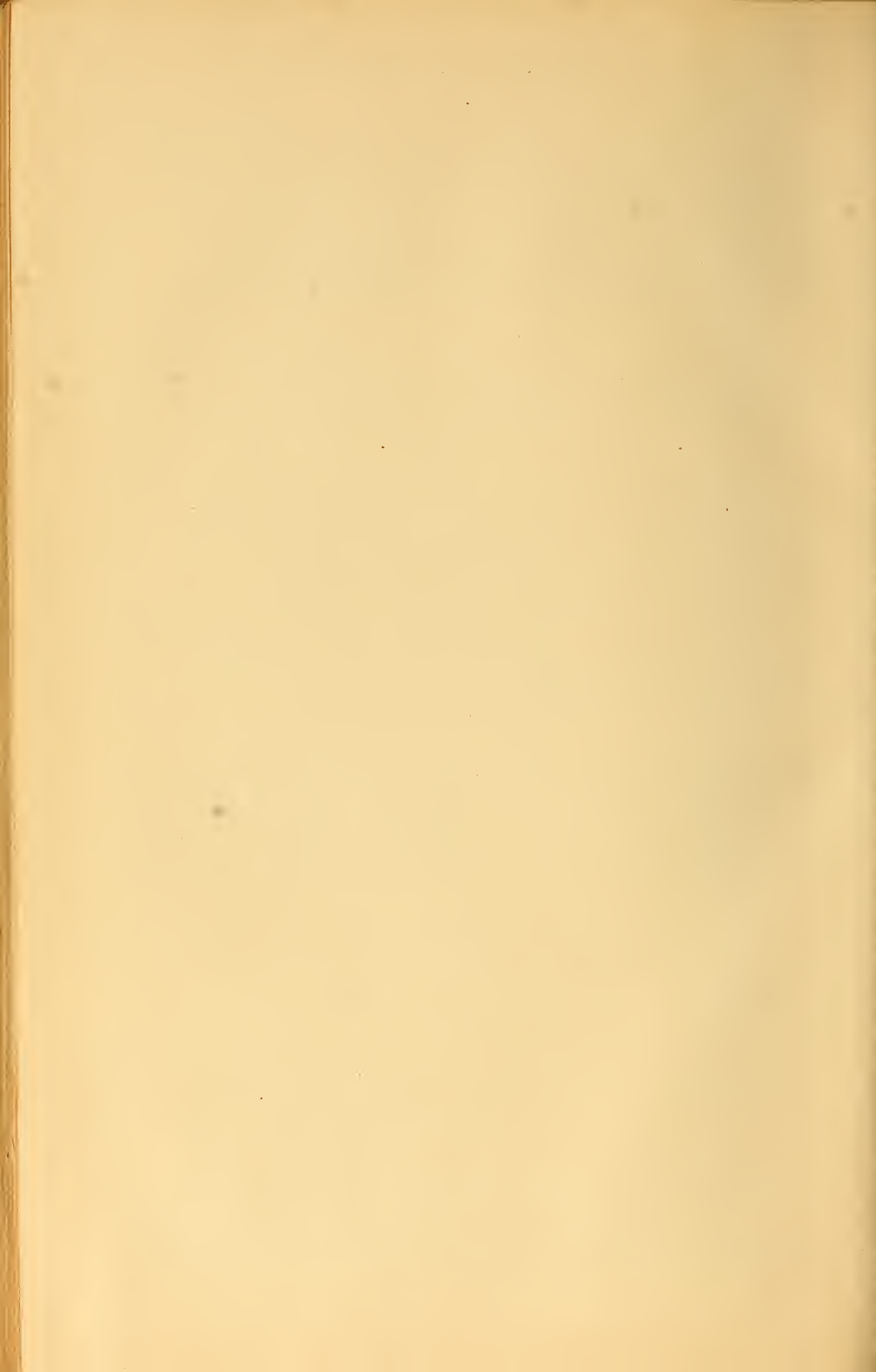
A Comprehensive Medical Dictionary, containing the Pronunciation, Etymology, and Signification of the Terms made use of in Medicine and the Kindred Sciences. With an Appendix, comprising a complete list of all the more important articles of the Materia Medica, arranged according to their medicinal properties; also an explanation of the Latin Terms and Phrases occurring in Anatomy, Pharmacy, etc.; together with the necessary directions for writing Latin Prescriptions, etc., etc. By J. THOMAS, M.D., author of the System of Pronunciation in "Lippincott's Pronouncing Gazetteer of the World." Demi 8vo. Cloth, \$3.00; leather, \$3.50.

From DR. W. H. VAN BUREN.

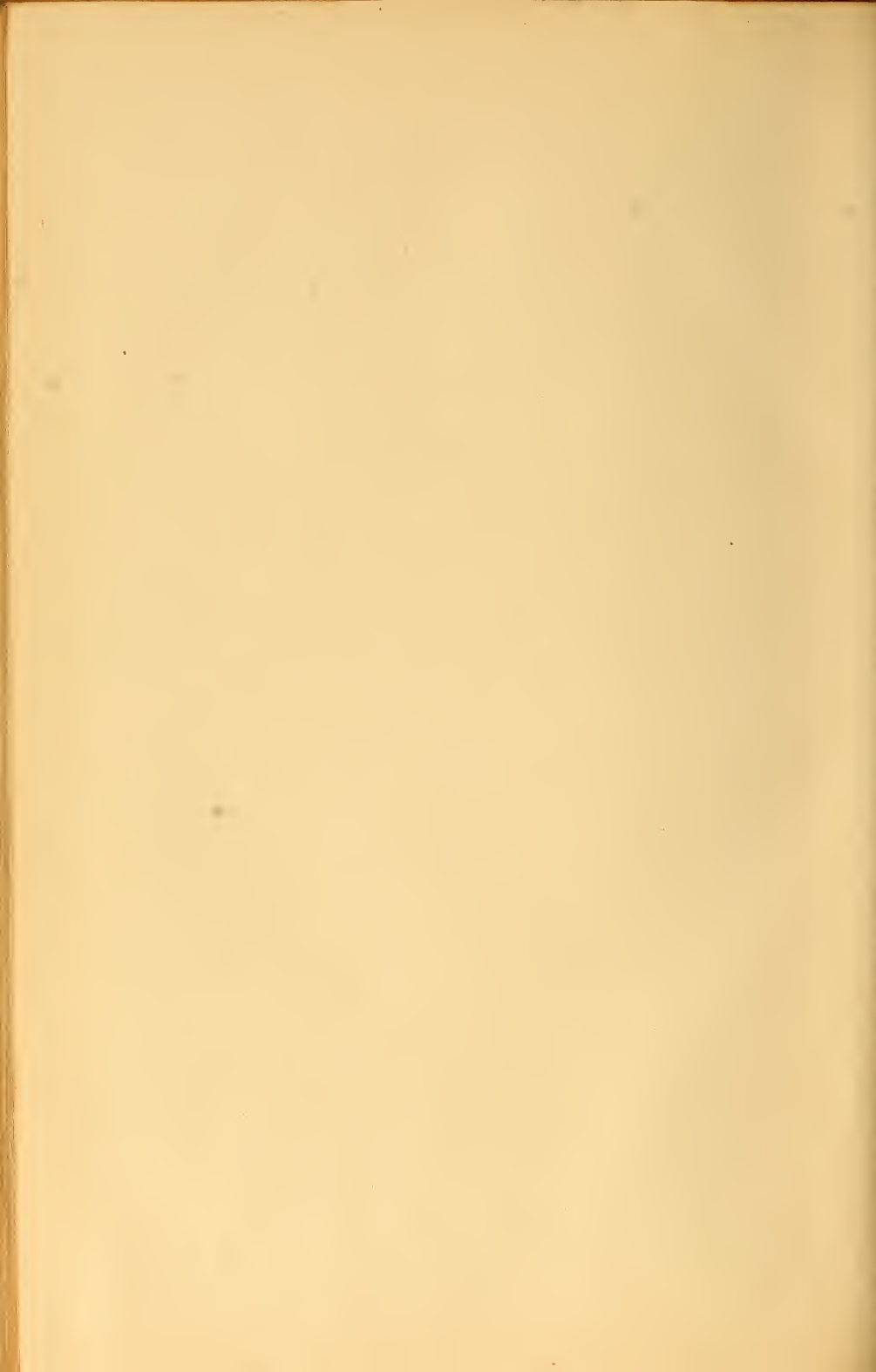
I regard Dr. Thomas's Comprehensive Medical Dictionary as the best dictionary of its size within the reach of the student and practitioner. Its directions for the pronunciation of Latin terms and

for the correct writing of prescriptions are especially valuable and complete. In typography and arrangement of matter it is admirable.

W. H. VAN BUREN, M.D.,
Professor Anatomy, University New York.











LIBRARY OF CONGRESS



0 021 062 414 4